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HUMAN FACTORS PLAN FOR MARITIME SAFETY

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A literature review, which was completed as a part of this project, has been summarized in the interim report, "Human Factors Plan for Maritime Safety: Annotated Bibliography," report number R&DC 05/93, February 1993.

16. Abstract

The purpose of this report is to present an integrated plan of human factors work oriented toward effectively implementing human factors in the U.S. Coast Guard and the maritime industry. The objectives for meeting this goal are threefold: (1) to identify the human factors issues affecting the regulatory, guidance and enforcement activities of the Coast Guard and those affecting operations in industry; (2) to determine the interrelationships among the issues; and (3) to propose specific human factors solutions that will provide a technical basis for regulation, guidance and design. As a result of numerous interviews, mostly with USCG headquarters personnel, 68 human factors issues were identified. A content analysis determined that these issues could be classified into five broad areas: (1) manning, qualifications and licensing, (2) automation design approaches, (3) safety methods and data, (4) communications, and (5) organizational practices. The issues were addressed by twenty-four detailed solution approaches (Appendix C). These technical approaches are sufficiently detailed to form the basis of Statements of Work for R&D projects. The primary products of these solution approaches are information, tools, and procedures for the effective implementation of human factors into the maritime environment. A suggested ordering of the different projects is given, taking into account that the information derived from several of these projects is a required precursor to other projects.

Subsequently, the USCG prioritized these proposed projects. The results of this prioritization process, prepared by the R&DC, are presented in Appendix D.

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METRIC CONVERSION FACTORS

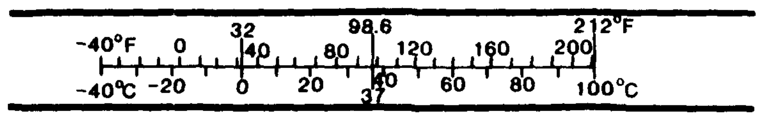
Approximate Conversions to Metric Measures

Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
in	inches	*2.5	centimeters	cm
ft	feet	30	centimeters	cm
yd	yards	0.9	meters	m
mi	miles	1.6	kilometers	km
		AREA		
in^2	square inches	6.5	square centimeters	cm^2
ft^2	square feet	0.09	square meters	m^2
yd^2	square yards	0.8	square meters	m^2
mi^2	square miles	2.6	square kilometers	km^2
	acres	0.4	hectares	ha
		MASS (WEIGHT)		
oz	ounces	28	grams	g
lb	pounds	0.45	kilograms	kg
	short tons (2000 lb)	0.9	tonnes	t
		VOLUME		
tsp	teaspoons	5	milliliters	ml
tbsp	tablespoons	15	milliliters	ml
fl oz	fluid ounces	30	milliliters	ml
c	cups	0.24	liters	l
pt	pints	0.47	liters	l
qt	quarts	0.95	liters	l
gal	gallons	3.8	liters	l
ft^3	cubic feet	0.03	cubic meters	m^3
yd^3	cubic yards	0.76	cubic meters	m^3
		TEMPERATURE (EXACT)		
°F	Fahrenheit temperature	5/9 (after subtracting 32)	Celsius temperature	°C

*1 in = 2.54 (exactly).

Approximate Conversions from Metric Measures

Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
mm	millimeters	0.04	inches	in
cm	centimeters	0.4	inches	in
m	meters	3.3	feet	ft
m	meters	1.1	yards	yd
km	kilometers	0.6	miles	mi
		AREA		
cm^2	square centimeters	0.16	square inches	in^2
m^2	square meters	1.2	square yards	yd^2
km^2	square kilometers	0.4	square miles	mi^2
ha	hectares (10,000 m^2)	2.5	acres	
		MASS (WEIGHT)		
g	grams	0.035	ounces	oz
kg	kilograms	2.2	pounds	lb
t	tonnes (1000 kg)	1.1	short tons	
		VOLUME		
ml	milliliters	0.03	fluid ounces	fl oz
l	liters	0.125	cups	c
l	liters	2.1	pints	pt
l	liters	1.06	quarts	qt
l	liters	0.26	gallons	gal
m^3	cubic meters	35	cubic feet	ft^3
m^3	cubic meters	1.3	cubic yards	yd^3
		TEMPERATURE (EXACT)		
°C	Celsius temperature	9/5 (then add 32)	Fahrenheit temperature	°F



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EXECUTIVE SUMMARY

Human-related error has been identified as a cause of 65 - 80% of the accidents in a wide variety of industries (Nagel, 1988). This general figure holds for the maritime industries, which have received relatively little attention in terms of human factors research. Commercial ships have not traditionally been considered as high-risk technological systems, yet the occurrence of numerous accidents, including the Exxon Valdez, demonstrate the catastrophic potential of human error in maritime systems. The purpose of this report is to present an integrated plan of human factors work oriented toward effectively implementing human factors in the U.S. Coast Guard (USCG), the maritime industry and the International Maritime Organization. The objectives for meeting this goal are threefold: (1) to identify the human factors issues affecting the regulatory, guidance and enforcement activities of the Coast Guard, and operations in industry; (2) determine the interrelationships among the issues; and (3) propose specific human factors solutions that will provide a technical basis for regulation, guidance and design.

A series of reports produced by the National Research Council and others, beginning in 1976, provides important background information for understanding the need for a detailed human factors plan at this point in time. These reports, published in 1976, 1981 and 1990 describe aspects of the human factors problem in commercial shipping, and call for the development of a research program. These reports call for more detailed problem analyses and technical specifications to develop human factors solutions. In particular, solutions should be linked to the Coast Guard marine safety mission and the means by which that mission is carried out. The work presented in this document represents the next step required in development of a human factors program, i.e., a detailed plan of human factors work aimed at specific issues within the maritime environment.

To facilitate the identification of human factors issues and solutions, the work was driven by a model of human factors in the maritime industry. Human factors can be conceptualized within the maritime environment in terms of five human and technological system domains: (1) ship personnel/human resources, (2) ship design and automation, (3) port operations, (4) navigation and traffic management, and (5) organizational factors. To identify human factors issues a total of 5 focus groups and 7 individual interviews were conducted, yielding a total headquarters sample of 32. Industrial participants were relatively few; we interviewed one manufacturer of automated display software, a manufacturer of navigation electronics and integrated bridges, and employees of a major oil shipping company.

A total of 68 human factors issues were identified. On the basis of content analysis, it was determined that a number of common needs underlie the issues, and span the charter of multiple Coast Guard and industry users. These objectives are meant to encompass broad areas in which specific technical solutions can be developed. Five objectives were defined as follows:

Manning, Qualifications and Licensing: Procedures to ensure adequate training and manning levels on board ships need to be developed. This includes ensuring that the human resources have the minimum qualifications necessary for licensing through testing or training course evaluation, and a task-based approach to work requirements for determining manning levels for safe operation.

Automation Design Approaches: Methods are required for incorporating human factors in the design and use of automated systems, so that operators will understand the concept of operations and form appropriate mental models during initial learning and routine use. Of particular importance is effectively integrating existing equipment (and skills) with new systems such as navigation electronics. The distribution of information to multiple workstations and personnel and the impacts of automation on job performance are areas in which work is required.

Safety Methods and Data: Better information and procedures are necessary to define safety problems and to control them. This includes incorporating human factors into shoreside facility and vessel inspection, casualty investigation and emergency response procedures.

Communications: Improvements in person-to-person and equipment-to-person communications (as in navigation aids such as markers and buoys) will reduce the confusion that sometimes arises with regard to intentions, location and necessity to respond. An understanding of information utilization by mariners will help to reduce crowding on radio channels.

Organizational Practices: Many human factors issues derive from organizational practices or policies that inhibit the flow of information in the engineering development process, or that fail to consider the human costs/benefits of potential regulations or work practices. Improvements in design processes and work structures will reduce potential human factors problems.

In order to achieve the desired level of specificity of human factors solutions, it is necessary to characterize the problems in sufficient detail to develop alternative approaches. Thus, we distinguished between <u>design-oriented</u> solutions, and <u>applied research solutions</u>. The former will result in products that will be more immediately applicable to the shipping industry, and include such things as better guidelines for alarm displays, criteria and methods for improving written procedures, and guidelines for communications between individual ship personnel, or between ship personnel and VTS. Examples of applied research areas include the impact of reduced manning on emergency response capability, appropriate design approaches to automating navigation tasks and the impact of regular sleep disruptions on acute and chronic fatigue. Since there is not a well-defined body of scientific

information that can be applied to these problems by means of tailoring existing solutions to the maritime environment, developing appropriate solutions will depend on conducting applied research. The goal of applied research is to develop the information required to generate specific design-oriented solutions.

Twenty four discrete solution projects were identified for the five objective needs, or human factors program areas. The overall problem areas and work requirements are described in Chapter 3; the detailed technical approaches are described in Appendix C. The fundamental product of the various program areas discussed in Chapter 3 is information; i.e., human factors work will result in data and principles that will facilitate the development of hardware and software by industry (or the specification of procurements by the Coast Guard), and the development or interpretation of regulations to enhance the marine safety mission.

A two year planning period was used to portray the work identified to address the human factors issues; this period is for illustrative purposes using arbitrary start dates. The more important aspect of the plan is that each of the program areas contains what are considered critical tasks that should be performed prior to other work being done. Some of the critical tasks feed the activities of subsequent tasks, while others are necessary simply to get the human factors program organized and under way. The following critical tasks have been identified: (1) job/task analysis of merchant marine work, (2) cognitive analysis of automation impact, (3) workload analysis of ship operations, (4) workload analysis of the Vessel Traffic System, (5) development of supplemental human factors information and investigation tools for the Marine Safety Manual, (6) organizational implementation of human factors within the Coast Guard, and (7) evaluation of shipping companies' responses to the work hour rules of the Oil Pollution Act of 1990. The total resource requirement for these critical tasks is 6.5 staff years in the first year, and 3.7 staff years for the second 12 month period. The total resource requirement over the length of the plan is estimated to be 24.1 staff years. Resource estimates were based on the expert judgment of experienced human factors professionals. The sequencing of tasks is specified in such a way as to permit the successive development of information, using data from earlier tasks; an example of this is performing a job/task analysis prior to developing a manning model. The information requirements for manning models are specified in a companion document (Lee & Sanquist, 1992).

The Human Factors Coordinating Committee (HFCC) will serve an integral role in the design and execution of the work described in this plan. The HFCC in conjunction with the human factors personnel from R&DC will provide continuing guidance for carrying out specific human factors solutions. Such guidance would include (but not be limited to) identifying pending regulatory action that could be affected by project results, linking the structure of tasks to planned or ongoing administrative initiatives, focusing the gathering of task-related information to facilitate the development of an internal product, such as a NVIC or guidance document, and providing input on

potentially useful casualty or investigation information. A primary function of the expanded HFCC will be to incorporate the results of the work described in this plan into a human factors technical basis for regulation. The general consensus of multiple studies by the National Research Council is that we currently lack this basis. Performance of the work described in this plan will establish an explicit human factors technical basis for evaluating and controlling maritime safety problems.

I. INTRODUCTION

Human-related error has been identified as a cause of 65 - 80% of the accidents in a wide variety of industries (Nagel, 1988). This general figure holds for the maritime industries, which have received relatively little attention in terms of human factors research. Most of the applied work in the field of human factors has been focused on industry-specific problems, such as nuclear power, aviation and military systems. Commercial ships have not traditionally been considered as high-risk technological systems, yet the occurrence of numerous accidents, including the Exxon Valdez, demonstrate the catastrophic potential of human error in maritime systems. The purpose of this report is to present an integrated plan of human factors work oriented toward effectively implementing human factors in the U.S. Coast Guard (USCG), industry and the International Maritime Organization. By following this plan, which identifies the significant human factors problem areas and proposed solutions, government and industry will have a basis and strategy for reducing the largest cause of maritime casualties. The primary goal of this report is to facilitate the US Coast Guard marine safety mission by providing a detailed plan for human factors work that will result in a technical basis for regulation and industry guidance. The objectives for meeting this goal are threefold: (1) to identify the human factors issues affecting operations in the maritime industry, and the regulatory, guidance and enforcement activities of the Coast Guard; (2) determine the interrelationships among the issues; and (3) propose specific human factors solutions that will provide a technical basis for regulation, guidance and design.

1.1 RATIONALE AND SCOPE OF PROJECT

In order to facilitate the development of a Human Factors Program to incorporate human factors into all USCG research, design operational, regulatory and guidance efforts, a strategic human factors program plan is required. Previous Coast Guard sponsored National Research Council (NRC) studies (see below) have indicated that one of the principal difficulties associated with incorporating human factors in the maritime industries is the lack of a comprehensive plan to guide the work. The focus of the work described in this report is to document existing and potential safety concerns related to human factors in shipping, and to propose solutions to these problems. The proposed solutions, and the strategy for carrying them out, will provide the USCG with a human factors technical basis to facilitate the marine safety mission for commercial vessels. That mission entails the following activities:

> Minimize deaths, injuries, property loss and environmental damage by developing and enforcing Federal standards for vessels, offshore facilities, merchant marine personnel and other facilities engaged in commercial or scientific activity in the marine environment (U.S. Coast Guard, 1990).

The scope of the work reported here will focus principally on commercial vessels, and to some extent shoreside operations. The results of this project will provide an important input to the general process used by the USCG to accomplish the marine safety mission, as shown in Figure 1. Human factors as a technical basis for evaluation of safety problems will serve to establish evaluation criteria, inspection and audit tools, and influence the further development of safety data. The resulting problem evaluations will result in decisions regarding regulation, guidance and enforcement that will take human factors into account. The dotted line around the human factors technical basis in Figure 1 signifies that it needs to be developed.

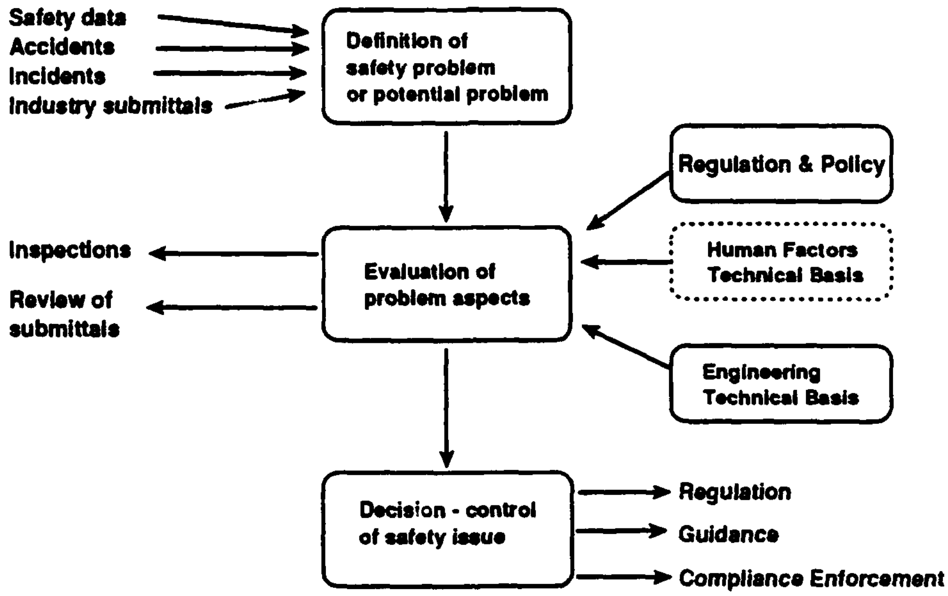

Figure 1. General Process for USCG Marine Safety Mission

The general approach used to accomplish the work reported here is shown in Figure 2. Through a process of interviews with headquarters personnel, industry contacts, observation of operations, and evaluation of scientific literature, human factors issues were identified and classified. Solutions were generated, based on the need for design specifications and applied research. An overall strategy is implicit in the classes of solutions developed (which have some overlap, of necessity); this strategy involves five classes of solution, which focus work in different ways; (1) manning qualifications and licensing, (2) automation design, (3) safety procedures and data, (4) communications, and (5) organizational practices. The specific work described by the solution proposals, the relationships between these classes of solution, the timing and resources required for implementation, and the products of the work constitute the plan for human factors implementation.

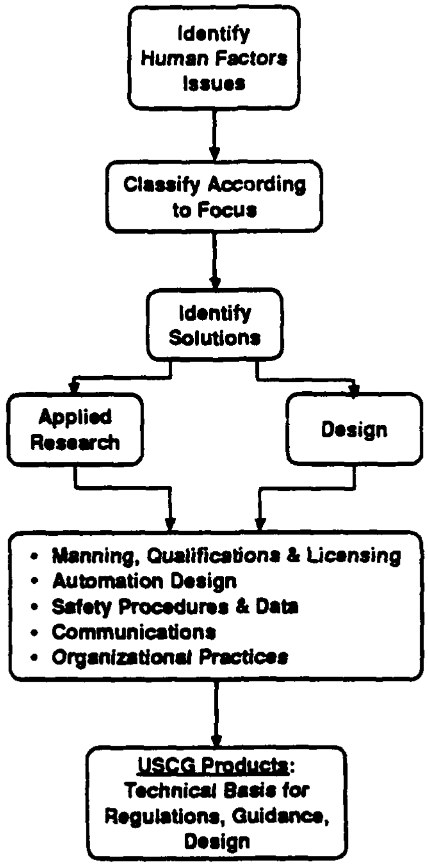

Figure 2. Human Factors Planning Process

The remainder of the first chapter provides historical background on previous analyses of human factors in the maritime environment, and describes a framework for addressing human factors.

1.2 HISTORICAL BACKGROUND

A series of reports produced by the National Research Council and others, beginning in 1976, provides important background information for understanding the need for a detailed human factors plan at this point in time. This section reviews these studies, and presents a synthesis of their conclusions.

1.2.1 Human Error in Merchant Marine Safety (1976)

This 1976 study followed from the finding of a 1970 project by the NRC that personnel fault was the most frequent cause of merchant marine vessel casualties. The 1970 project called for a more detailed investigation into this problem. The 1976 report focused on gathering data from merchant marine personnel by means of a written survey and interview procedure. This remains one of the only examples we have found of quantitative data gathering directly from mariners actively involved in the trade.

The survey was developed on the basis of 74 interviews; a total of 153 interviews were completed. 1400 questionnaire forms were sent to various organizations, including unions, pilots associations, maritime academies and shipping companies. The response rate was 18.1% (254 usable surveys were returned). The 192 item questionnaire used the critical incident technique, and sought to identify the root causes of human error. The resulting data suggested a number of factors related to personnel failure, including: (1) inattention, (2) ambiguous pilot-master relationship, (3) inefficient bridge design, (4) poor operational procedures, (5) poor physical fitness, (6) poor eyesight, (7) excessive fatigue, (8) excessive alcohol use, (9) excessive personnel turnover, (10) high level of calculated risk, (11) inadequate lights and markers, (12) misuse of radar, (13) uncertain use of sound signals, and (14) inadequacies of the Rules of the Road. Recommendations were developed for most of these categories, including the installation of collision avoidance systems and research and development designed to improve the state of knowledge and design in the various areas described. Additional information provided in this report included casualty flow diagrams and job functional analyses of ship personnel that are presented at a level that aggregates many component tasks (e.g., watch-standing) and causal factors (e.g., improper operation). More detailed analyses will provide the basis for implementing human factors solutions.

Since this survey was conducted, there have been a number of technological and regulatory changes that influence some of the causes listed, such as the development of Automated Radar Plotting Aids (ARPAs), fitness for duty regulations and work-hour regulations. There are notable parallels between the problems identified 16 years ago, and today, suggesting the fundamental importance of human factors. Thus, this study was important for the insight it offered, and provides a basis for applying human factors conceptions of root causes that have become more sophisticated on the basis of developments in cognitive psychology.

1.2.2 Research Needs to Reduce Maritime Collisions, Rammings and Groundings (1981)

A subsequent Commission on Sociotechnical Systems of the Maritime Transportation Research Board convened to evaluate research needs relative to specific types of casualties. This commission used a

functional flow block diagram (FFBD) technique to delineate the sequence of events that transpire to lead to a collision, ramming or grounding. The report surveyed the available data sources for human factors information, and concluded that while there is a rich body of basic data available, little of it is applicable to the marine environment. The report called for an integrated program of research "for finding the root causes of human error in maritime casualties." It further recommended programs of human factors work to "establish industry guidelines for layout and display of control equipment for bridges and engine rooms." The commission found that the situation with respect to human factors and maritime safety was in a poor state because of the lack of "a comprehensive plan for coordinating maritime research."

1.2.3 Major Marine Collisions and Effects of Preventive Recommendations (1981)

This study by the National Transportation Safety Board (NTSB) evaluated 82 marine accidents occurring between 1970 and 1980. It was determined that 66% of the collision accidents were the result of human error, predominantly in the area of improper navigation. Examples included radar-assisted collision and failure to communicate to other ships regarding intentions. A number of areas where recommendations were made to the Coast Guard and industry were reviewed. In the area of personnel, only 4 of 34 recommendations of the NTSB had been closed. While the recommendations of the NTSB tend to be very specific based on the circumstances of individual accidents, the general themes of improved practices in training, licensing and manning emerge. The report reiterates the importance of systematically addressing the major cause of marine collisions - human error.

1.2.4 Shipboard Crew Fatigue, Safety and Reduced Manning (1990)

Work conducted by the Volpe National Transportation Systems Center (VNTSC) was aimed at better defining the relationship between manning levels and fatigue in shipboard operations. The principal method of the study was based on ship rides and visits with five different ships, including tankers and cargo ships. Attempts were made to apply standardized fatigue, workload and activity surveys, but met with some resistance from the ship personnel, and so little quantitative data was available from this study. Subjective impressions based on self-report of a small number of cooperative personnel provided the basis for conclusions. It was generally reported that organizational variables (i.e., company policies) were the principal determinants of levels of fatigue where improvements were feasible (other factors included voyage scheduling, ship design, and physical environment). The issue of manning scale was not evaluated. It was recommended that more detailed data be collected, to evaluate the response of industry to new work rules, and the impact of greatly reduced numbers of ship personnel (e.g., 11 or fewer) on work structure and fatigue.

1.2.5 Crew Size and Maritime Safety (1990)

A somewhat more comprehensive effort to address the issue of the number of ship personnel was undertaken by the National Research Council (1990). This report reviewed trends in decreased manning scales, safety trends, the capabilities of automation, the regulatory framework in which U.S. flag shippers operate, and the human factors aspects of the number of ship personnel. This latter aspect is of most concern for the present work, and involved articulating the concept of a ship as a complex sociotechnical system, to which systems engineering approaches need to be applied. The main issue addressed was the need for a rational basis, or manning model, upon which to base crew size decisions. Functional task analysis was described as the basis for developing such a model, and a high-level functional analysis of shipboard activities was provided. The report described a manning model that was developed on the basis of expert judgment input from two shipping companies, and applied to operational and emergency scenarios. It was concluded on the basis of the model that crew size could be substantially reduced on existing ship platforms without adversely affecting safety.

While this model provides a good initial estimate of manning requirements, additional refinements could enhance its accuracy. For example, the model contains estimates of the frequency and duration of a wide variety of tasks, yet it contains no information concerning human performance limitations, such as the possibility of errors. Furthermore, the level of detail of these tasks is relatively high, describing tasks with the greatest detail as: "cleaning/wash down of deck", "vessel fabric maintenance", "helicopter operations", "inert gas operations", and "inert gas unscheduled maintenance". In addition to the limitations associated with the content of the model, using a spreadsheet limits the output of this model to a simple summation of the number of hours required by each skill categories. Using this technique prevents the model from revealing possible concurrent activities that would require the simultaneous presence of a single person at different parts of the ship. Likewise, the spreadsheet does not show the distribution of workload across personnel and time. For instance, the model could not differentiate between a task requiring two persons for two hours or one person for four hours. Task B (Lee and Sanquist, 1992) illustrates how other modeling techniques might overcome these limits.

The NRC report concludes with a number of recommendations, which include the use of formal analytical methods, such as functional analysis, to facilitate manning decisions. The conclusion presupposes that there are sufficient data upon which to base a model, which our review of the scientific literature indicates is not the case. Thus, while it is conceptually possible to use formal human factors methods to facilitate Coast Guard decision making, a considerable amount of work must be performed to translate existing human factors data to the maritime environment, and to obtain that data where knowledge is lacking.

1.2.6 General Scientific Literature

As part of the work conducted in this project, an evaluation of the scientific literature in human factors was conducted, to assess the extent to which human factors information exists that is pertinent to the maritime environment. Well over 100 articles (in addition to those described above), technical reports and design guidelines or standards were identified. Volume II of this report contains an annotated bibliography describing the detailed contents of each article.

Evaluation of the literature indicated that several themes predominated in maritime research that deal directly or indirectly with human factors; these include shipboard manning, automation and electronics, fatigue and standards for design. A variety of approaches to manning were identified, although the generality of the approaches indicates further work is required to answer questions about specific ship personnel complements. Similarly, a significant number of articles described new approaches to shipboard automation, but did not evaluate the human performance impacts of the new equipment. The domain of fatigue and work scheduling has received focused study by Colquhoun (e.g., 1985), and alternative watch schedules that may be better from a human performance standpoint are discussed. However, there is no attention given to the regulatory and labor policy issues that are involved in this problem. Design standards and methods for Human-System Integration (HSI) have been developed extensively by the Department of Defense (e.g., MIL Handbook 763, ASTM F1166), yet do not appear to be routinely incorporated in the design and testing of shipboard systems. Volume II provides further discussion of the scientific and technical literature that was evaluated in the preparation of this plan.

1.2.7 Human Factors Planning in Other Industries

The human factors discipline often increases in importance when a catastrophic accident or series of accidents focuses public attention in an area. This has certainly been the case with the Exxon Valdez, and human error has been implicated in a number of other highly visible accidents, including the Three Mile Island loss of coolant accident, and the failure of a pilot to lower the flaps of a large jetliner on takeoff, leading to a fatal crash. As a result of more focused attention on human factors in the nuclear and aviation industries, the Nuclear Regulatory Commission (1982) and the Federal Aviation Administration (1990) undertook comprehensive planning efforts to specify the work required in human factors to improve overall system performance and safety. Further, impending technological developments in advanced vehicle control systems have resulted in a human factors plan under the auspices of Intelligent Vehicle Highway Systems of America (1992). This section briefly reviews these planning efforts.

Nuclear Industry

Following Three Mile Island, the Human Factors Society was commissioned by the Nuclear Regulatory Commission (NRC) to recommend a long-range research plan for human factors in the nuclear industry. The project staff consisted of human factors experts who were given brief tutorials in the fundamentals of nuclear power, and who then worked with NRC and industry staff to define issues and research needs. The principal finding of the study group was that prior to Three Mile Island, human factors analysis was virtually non-existent in the nuclear industry. Thus, a significant percentage of recommendations were oriented toward establishing a human factors activity within the NRC. A number of other areas were identified as high priority, including: Annunciators and Alarms, Training, Qualifications and Licensing, Shiftwork procedures (and fatigue effects), and Safety Parameter Display Systems.

The NRC plan specified a 10 year period in which various project areas would be addressed. Significant applied human factors research has been sponsored by the NRC following the implementation of aspects of the plan. An early criticism of the plan was that it overprescribed and was too much to be done with the time and resources available. Most of the areas that were identified as high priority have received adequate attention, and have resulted in regulation and guidance for the industry.

Aviation Industry

The predicted increase in air travel in the last decade of the 20th century, and the improvements in equipment reliability has helped to focus attention on the human factor as a way to increase the margin of safety in air travel. The Aviation Safety Act of 1988 specifically authorized the expenditure of $25 million annually to improve human factors and safety. In late 1988, the FAA established the position of Chief Scientific and Technical Advisor for Human Factors. One of the first activities of this office was to develop a long-range plan for human factors in aviation.

The method used by the FAA was somewhat different than that of the NRC; rather than using a core group of human factors experts, distinct scientific task planning groups were convened. These groups consisted of human factors personnel, and subject matter experts in particular areas such as air traffic control or maintenance. The planning groups used a high-level human factors plan developed by the Air Transport Association as a basis for further specifying the work required. The resulting plan focused research in specific application areas, such as the cockpit environment, air traffic control, cockpit-air traffic integration, aircraft maintenance and airways facilities maintenance. Each of these areas is focused on common plan objectives in the following areas: Automation, System Monitoring, Basic Human Performance Knowledge, Human Performance Measurement, Information Transfer, Controls and Displays, Training and Selection, and Certification and Validation Standards. Since the

aviation human factors plan is relatively new, assessment of its success is difficult. There have been reports from high-level FAA officials that the plan has helped to focus research across a number of labs.

Highway Safety

Advances in sensor and control technologies makes the prospect of an "intelligent vehicle highway system" (IVHS) appear realistic. Such a system would involve a combination of vehicle and satellite-based sensor technologies, and command and control (traffic management) systems that would facilitate the flow of traffic. In the most futuristic scenario, the driver would not control the car at all, but rather relinquish control to in-vehicle systems that would be linked to a large-scale traffic management system. In 1990, IVHS America was formed as an advisory body to the National Highway Traffic Safety Administration. This group has formed committees to plan for the research and development requirements necessary to achieve the implementation of this technology.

The human factors and safety committee of IVHS America developed a research plan to identify human factors issues and research requirements. Subcommittees in each of four areas (Advanced Traveler Information Systems, Advanced Vehicle Control Systems, Commercial Vehicle Operations, and Advanced Traffic Management Systems) met for 2 days, and generated issues which were subsequently consolidated. The resulting issues span a wide range of human factors problems. Automation was the most salient issue in all areas, in terms of operator workload both in driving and traffic management, and trust in the systems. This latter issue is particularly important in this domain, since drivers will essentially allow automated systems to control their fast moving cars. The level of detail provided by this plan is relatively low compared to the FAA and NRC. This is because IVHS is a technology at its inception, and it is first necessary to identify the salient questions; as the direction of system implementation becomes established, then specific research programs can be undertaken. No resource estimates have been provided for undertaking the research specified in the IVHS plan.

1.3 HUMAN FACTORS IN THE MARITIME ENVIRONMENT

The application environments which have received the most attention from the human factors community include military systems, aviation, and nuclear power. In each of these areas, there are well-established communities of government and industry personnel concerned with research and development related to human-systems integration in design, and test and evaluation of new systems. The three primary applications derived from deficiencies in system performance (e.g., power plant personnel making errors leading to radiation releases), and resulted in the eventual establishment of comprehensive research and development programs to ensure the application of human factors throughout the design cycle of these complex technological systems. Nuclear power is the most recent

addition to the group, and was driven primarily by the Three Mile Island accident. Areas where human factors is finding increasing application are the computer industry, telecommunications and advanced automotive technologies. There is increasing recognition that human factors is an integral part of a total quality approach to system design and management, and that the end-users and operators of technology must be involved in all phases of the process.

In the maritime industries, there has been considerably less attention devoted to human factors. This is due in part to the long-standing traditions associated with shipping, and to the government view that human factors are implicit in the regulations, i.e., as long as companies or ships are in compliance, there are no human factors problems. While this "embedded philosophy" may have been effective for an era in which ships routinely carried a highly redundant personnel using relatively low technology, it appears to be time to explicitly address the role of human factors in marine safety in a comprehensive way. (It is worth noting that other industries employing dangerous technologies are well-behind in explicitly addressing human factors - notably the chemical processing and refining industries.) This conclusion is reinforced by several factors: (1) a series of studies by the marine board of the National Research Council, and others, demonstrating the large role played by human error in marine accidents; (2) the increasing world economic pressures to reduce crew sizes; (3) advanced technologies that potentially allow such reductions in crew sizes; and (4) the recent passage of the Oil Pollution Act of 1990 (OPA '90), which specifies a number of potential regulations concerning the human role in shipping. The passage of the act was stimulated largely by the March, 1989 grounding of the Exxon Valdez, which was shown to be the result of numerous human factors problems (NTSB, 1990).

The U.S. Coast Guard has acknowledged the need for work in human factors for a number of years. The RDT&E Plan for Marine Safety (1977), which presented research needs to support the USCG's marine safety activities, proposed several projects with human factors components. The NKF study (Reese, et al., 1990), another wide-scope study of research needs within marine safety, noted about a dozen human factors aspects that would benefit from further research. The AIM (Automation Information Management, 1989) study proposed a five-year plan for human factors, primarily in the area of marine investigations. Human factors elements are also represented in the Oil Pollution Research and Technology Plan (1992), an interagency research plan developed in response to the OPA '90 legislation. The current report is the first to focus explicitly on human factors in support of the marine safety program.

The Coast Guard has sponsored human factors research in the past, most notably in the design of aids to navigation, where human factors data has been applied to increase the conspicuity of short-range aids. Some of the recent work in human factors includes: the revision of the human factors taxonomy used by CG marine investigators to determine the root causes of a casualty; a quantitative analysis of the human and organizational errors that contribute to marine casualties (Bea and Moore, 1991; Moore and Bea, 1992); the preparation of the <u>Waterway Design Manual</u> (Smith, 1992), which blends human

performance data with engineering models to aid the design of channels; and a review of modeling techniques that could assist the CG in determining safe manning levels for merchant vessels (Lee and Sanquist, 1992). This year the Coast Guard has also sponsored a lecture series to increase the awareness of its headquarters staff on human factors issues.

Interest in human factors has escalated in the last few years, precipitating the present planning study. The Coast Guard realizes that human factors has the potential to make contributions to many areas of marine safety. This plan will serve as a guide for applying human factors to specific problems identified by the Coast Guard as being important to marine safety.

Human factors can be conceptualized within the maritime environment in terms of five human and technological system domains: (1) ship personnel/human resources, (2) ship design and automation, (3) port operations, (4) navigation and traffic management, and (5) organizational factors. These system domains provide a framework for considering the numerous factors influencing human performance in the maritime environment. The framework implies that there are system variables, such as technology (displays, controls, ship designs), and internal variables, such as workload, fatigue, and attention. The latter variables have been referred to as **performance shaping factors**, or PSFs. System variables and PSFs combine in the operational shipping environment to yield human performance consequences and system performance outcomes. Figure 3 illustrates the relationship between these classes of variables and potential safety outcomes.

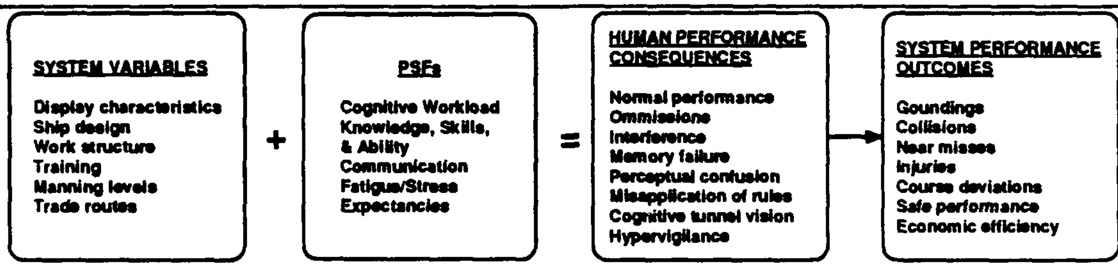

Figure 3. Relationship of System Variables, Performance Shaping Factors (PSFs), Human Performance, and Shipping Safety

An example of this type of interaction would be a compelling technology, such as ARPA, combined with stress, leading to cognitive tunnel vision and subsequent ship grounding. This is exactly what happened in the Exxon Valdez accident, in which the third mate, overly fatigued and stressed with a dramatic transition in workload when the captain left the bridge, focused too narrowly on what appeared to be the most relevant information at the time, i.e., the location of the ice on the radar screen (forgetting that the submerged portions of Bligh Reef would not show up and not paying sufficient attention to the autopilot mode); this cognitive tunnel vision (a human performance consequence) was the direct cause of the grounding.

The role of human factors is to influence how PSFs are manifested during job performance, so that human performance outcomes will result in error-free or error-correcting performance. This can be accomplished through a variety of means, including changing the design of equipment, improving the training of personnel, and altering the work structure or job design. The challenge of applying human factors knowledge in the maritime environment is to provide the government and industry with data, methods and procedures to ensure that system variables and PSFs combine to yield effective human performance and safe and economic system outcomes.

1.4 ORGANIZATION OF THE REPORT

Chapter 2 discusses the methods used to identify specific problem issues faced by the Coast Guard and industry that are related to human factors. Chapter 3 presents a series of high-level solutions that address multiple human factors issues. The fourth chapter delineates a strategy for accomplishing the work required by the planned solutions, in terms of relationships between solutions and products. A series of Appendices provides more detail on aspects of the planning process described in the main report: Appendix A provides an expanded version of the human and technological domains comprising the framework for the planning process; Appendix B contains the specific human factors issues identified during interviews and focus groups; Appendix C presents detailed descriptions of specific technical approaches to human factors solutions.

II. HUMAN FACTORS ISSUES IN THE MARITIME ENVIRONMENT

In order to develop a human factors plan that addresses the needs of the user community, a wide scope survey of Coast Guard HQ personnel, and some industrial concerns, was conducted. This chapter describes the process of data collection and analysis. The procedures used in this planning effort followed standard strategic planning approaches (Millett and Honton, 1991).

2.1 DEFINITION OF HUMAN FACTORS ISSUES

The first step in the definition of human factors issues was the development of a structured interview protocol and discussion guide. The contents of the discussion guide were based on the five-domain framework described in the previous chapter, and described more fully in Appendix A. The purpose of the discussion guide was to stimulate the respondents to think about areas that were particularly pertinent to their areas of expertise (e.g., manning, navigation, ship design, etc.), and to consider the potential relationship of human factors to those areas. The discussion guides were provided to prospective respondents a week in advance of structured interviews and focus groups.

The method of eliciting specific human factors issues relied on the use of structured interviews and focus groups. The focus groups essentially involved conducting a series of structured interviews in a session with multiple respondents. Focus groups were composed of personnel from related areas within Coast Guard HQ, such as MVP and MVI, and industrial respondents.

For Coast Guard and MARAD personnel, a total of 5 focus groups and 7 individual interviews were conducted, yielding a total HQ sample of 32. Industrial participants were relatively few; we interviewed one manufacturer of automated display software, a manufacturer of navigation electronics and integrated bridges, and employees of a major oil shipping company. These latter interviews were conducted aboard an oil tanker during a 4 day voyage to Valdez, AK. In addition to yielding useful interview data, the voyage permitted project staff to observe the operational aspects of shipping first-hand, and to evaluate potential areas where human factors solutions may be applied. Observations of all aspects of tankship operation were made, including cargo offloading, undocking, vessel piloting, bunkering, deck and engine department watches, traffic avoidance maneuvers, docking, and cargo loading.

2.2 CONTENT ANALYSIS OF ISSUES

The data obtained through the interviews were subjected to a content analysis to determine the common thematic elements mentioned by respondents. The initial step in this process was to reduce

the individual interviews to a series of single statements that could be easily manipulated. An example of such a statement is "Regulations specify personnel requirements without consideration of operational task demands." The individual statements were then scanned for content, and multiple statements of the same theme were combined. The next step involved classifying the statements according to the categories used in the discussion guide: (1) Crew Systems/Human Resources, (2) Port Operations, (3) Navigation and Traffic Management, (4) Ship Design and Automation, and (5) Organizational. An additional category was developed for a number of issues related to internal USCG needs, and was labelled "USCG Internal." Separate classifications of the individual issues were made by a group of human factors psychologists; where there were divergences in classification, discussion was used to resolve the discrepancies. Appendix B contains a detailed listing of the individual issues identified in the interview process. Table 1 shows the numbers and percentages of issues falling into each classification category.

Table 1. Human Factors Issues Classified By Technical Domain

Domain	Number of Issues	Percent of Issues
Crew Systems/Human Resources	16	24%
Ship Design & Automation	14	21%
Navigation & Traffic Management	10	15%
Port Operations	4	6%
Organizational	2	3%
USCG Internal	22	32%
TOTAL	**68**	**100%**

It can be seen that the largest percentage of the issues fall into the USCG Internal domain. This is not really surprising, given that the sample consisted primarily of USCG personnel. It should be stressed, however, that the relative importance of human factors issues is not determined solely on the basis of their proportion within the content analysis.

Additional input for issue definition was obtained from the scientific and technical literature, and from our observations of shipboard activities. In general, the issues defined by the industry and USCG interviews encompassed issues that surfaced from these other two sources. The issues that were identified and classified were subsequently reviewed with sample respondents for clarification and feedback. The feedback indicated that our analysis accurately represented the issues.

2.3 DEVELOPING HUMAN FACTORS SOLUTIONS

Classifying issues by their relationship to a technical domain is only one way of looking at them, and provides a problem orientation. However, since the purpose of this plan is to identify solution strategies, the issues were also classified according to a set of objectives that were defined on the basis of the content of the 68 issues. It was determined on the basis of issue content that a number of common needs underlie the issues, and span the charter of multiple Coast Guard and industry users. This was reflected in consistent themes within the individual issues, such as training, licensing, automation, safety data, etc. Each of these themes cuts across a wide spectrum of potential beneficiaries of human factors solutions. In order to accommodate a broad range of prospective users of human factors data, the common issue themes were used to define objectives of a human factors program. These objectives are meant to encompass broad areas in which specific technical solutions can be developed. Five objectives were defined as follows:

Manning, Qualifications and Licensing: Procedures to ensure adequate training and manning levels on board ships need to be developed. This includes ensuring that human resources have the minimum qualifications necessary for licensing through testing or training course evaluation, and a task-based approach to work requirements for determining manning levels for safe operation.

Automation Design Approaches: Methods are required for incorporating human factors in the design and use of automated systems, so that operators will understand the concept of operations and form appropriate mental models during initial learning and routine use. Of particular importance is effectively integrating existing equipment (and skills) with new systems such as navigation electronics. The distribution of information to multiple workstations and personnel and the impacts of automation on job performance are areas in which work is required.

Safety Methods and Data: Better information and procedures are necessary to define safety problems and to control them. This includes incorporating human factors into shoreside facility and vessel inspections, casualty investigations and emergency response procedures.

Communications: Improvements in person-to-person and equipment-to-person communications (as in navigation aids such as markers and buoys) will reduce the confusion that sometimes arises with regard to intentions, location and necessity to respond. An understanding of information utilization by mariners will help to reduce crowding on radio channels.

Organizational Practices: Many human factors issues derive from organizational practices or policies that inhibit the flow of information in the engineering development process, or that fail to consider the human costs/benefits of potential regulations or work practices. Improvements in design processes and work structures will reduce potential human factors problems.

Table 2 illustrates the numbers and percentages of issues falling into each of these categories.

Table 2. Issues Classified By Planning Objective

Objective	# of Issues	Percent of Issues
Manning, Qualifications & Licensing	19	28%
Automation Design Approaches	16	24%
Safety Methods & Data	13	19%
Communications	7	10%
Organizational Practices	13	19%
TOTAL	**68**	**100%**

The largest percentage of issues fall under the Manning, Qualifications and Licensing objective. The next largest percentage of issues is related to the Automation objective. The percentages may change somewhat from the classification by technical domain, since the focus of objectives is on solutions. Thus, it may be appropriate to solve an automation-related issue such as training with a manning-related solution involving qualifications approval. Safety Methods and Data encompass a number of inspection and investigation technical issues that must be solved with improved information and methods. Communications represents a smaller percentage of total issues, which tend to be focused in the areas of equipment design, such as markers, and traffic control communications. A number of specific human factors issues appeared to be indicative of organizational approaches that can be addressed either through new or revised regulation, or development of design processes and supporting documentation that provides human factors guidance. The objectives will provide solutions that can be related to the needs of multiple end-users in the Coast Guard and industry. Solution to technical approaches were developed by a team of human factors experts, oil spill prevention specialists, accident investigators, procedure writers and operational maritime experts. The following chapter describes the elements of a program that will result in meeting these objective requirements.

III. HUMAN FACTORS SOLUTIONS

3.1 INTRODUCTION

The previous chapter described the procedures used in this work for identifying and classifying human factors issues. The technical domains provided problem examples, while classification of the issues by objective helped to focus on potential solutions. This chapter builds upon the definition of objectives to focus on programmatic approaches to human factors problems. Each of the five objectives will be related to broad problem definitions, and the requirements for products to address the problems. Brief discussions of technical approaches will be provided; more detailed discussions of individual technical approaches will be provided in Appendix C. Before describing the human factors program areas, it is important to present some fundamental information concerning the general approaches and tools that the technical approaches require.

3.2 SOLUTION TYPES AND HUMAN FACTORS TOOLS

Many of the issues defined during the Coast Guard and industry interviews involve some type of mismatch between the requirements of the job, and the capabilities or limitations of ship personnel, either individually or as a group. From the Coast Guard standpoint, the principal means of dealing with such mismatches is either to interpret existing regulation with a view toward what constitutes a safe situation, or to provide guidance to industry in the form of information (e.g., NIVCs, policy guidance letters, Marine Safety Manual information, etc.); for example, individual ship manning levels are specified on the Certificate of Inspection, which is based both on regulations and supporting data submitted by the owner. Additionally, the development of resolutions by the International Maritime Organization can foster the implementation of human factors (e.g., see MSC 60). In both cases, the development of the technical basis for human factors implementation depends on quantifying the aspects of the human factors problem. The response of industry to regulation, guidance and international resolutions depends on the ability of the Coast Guard and IMO to provide guidelines for implementation that are specific enough to result in action, without being overly prescriptive.

In order to achieve the desired level of specificity of human factors solutions, it is necessary to characterize the problems in sufficient detail to develop alternative approaches. Thus, it is worthwhile to make the distinction between <u>design-oriented</u> solutions, and <u>applied research solutions</u>. The former will result in products that will be more immediately applicable to the shipping industry, and include such things as better guidelines for alarm displays, criteria and methods for improving written procedures, and guidelines for communications between shipboard personnel or ship personnel and VTS. It is possible to develop relatively concrete solutions in such areas because models exist for

solutions in other application domains (e.g., defense, aviation, nuclear); thus, for certain of the issues defined, the principal approach to solution will involve quantifying the nature and extent of the problem, and determining the applicability of design approaches that may involve display configurations, communication protocols, graphics methods, etc. It is important to realize that even though there are potentially applicable solutions available, their implementation in the maritime industries depends on a thorough understanding of how the problems manifest themselves in terms of the personnel involved, the working environment, and the frequency and density of information transfer. Another way of stating this is that the unique aspects of the maritime environment must be considered in applying human factors solutions.

Another class of issues is less amenable to immediately applicable solutions because of a lack of fundamental knowledge in a particular area. Examples of these types of issues include the impact of reduced manning on emergency response capability, appropriate design approaches to automating navigation tasks and the impact of regular sleep disruptions on acute and chronic fatigue. Since there is not a well-defined body of scientific information that can be applied to these problems by means of tailoring the solutions to the maritime environment, developing appropriate solutions will depend on conducting applied research. The goal of applied research is to develop the information required to generate specific design-oriented solutions.

Both design oriented and applied research solutions will be based on the application of specific human factors methods to characterize the application of existing human factors knowledge, and to develop the necessary knowledge to generate design alternatives. Table 3 identifies the human factors tools that are applicable to the issues that have been identified, and briefly indicates the output of the tool.

Detailed discussions of each of these methods can be found in standard human factors reference materials (e.g., Meister, 1985). The important aspect of the table from the standpoint of strategic planning for human factors is that there are well-developed methods for approaching a variety of problems encountered across many working situations. While there is not necessarily a one-to-one mapping of human factors issues or objectives to these methods, certain problem areas lend themselves to analysis with particular approaches. For example, to evaluate the potential manning implications of an automated navigation electronics system, a combination of job/task analysis, cognitive analysis, and link analysis would need to be performed. The job analysis would reveal current responsibilities and qualifications; the knowledge, skills and abilities (KSAs) necessary to perform tasks; cognitive analysis would identify new tasks and their requirements; and new mental workload demands imposed by automation; link analysis will show the influence of human-mediated communication and will identify potential manning changes that can result from automation. All aspects are important in determining how to design, implement, train and regulate new equipment or systems. The application of appropriate human factors techniques to address problem issues is the focus of the remainder of this chapter.

Table 3. Human Factors Tools and Products

Human Factors Tool	Product of Tool
Job/Task Analysis	Detailed list of job functions and specific tasks, and knowledge, skills and abilities necessary. Requirements for human-machine interaction.
Cognitive function/task analysis	Description of mental processes required to perform tasks; input/output structure.
Workload analysis	Task timelines, event frequency, interference potential.
Link analysis	Description of human-machine and human-human interactions in task performance.
Critical incident analysis	Detailed behavioral/situational descriptions of effective or ineffective performance.
Survey	Broad sample of data from multiple sources.
Literature search	Definition of applicable knowledge base.
Experimental analyses	Quantitative analyses of Performance Shaping Factors.

Application of the methods described in Table 3 will facilitate the work required of the five objectives, or human factors program areas, required to address the diverse range of human factors issues affecting the maritime industries. Sections 3.3 - 3.7 describe the general problem areas and solution approaches required in these five areas: (1) Manning, Qualifications, and Licensing; (2) Automation; (3) Safety Methods and Data; (4) Communications; and (5) Organizational Practices. The detailed technical approaches required in each of these areas are described in Appendix C.

3.3 MANNING, QUALIFICATIONS AND LICENSING PROGRAM AREA

One of the primary means by which the Coast Guard ensures that adequate numbers of properly trained personnel serve aboard ships is through manning evaluations and licensing procedures. Economic pressures continue to lead industry toward human resource reductions as a money-saving measure. Ensuring that proper numbers of appropriately trained personnel serve aboard ships is complicated by the introduction of automation. Procedures and data that facilitate making manning

and licensing decisions, and which incorporate knowledge about human capabilities and performance, are required. Developments in this program area require fundamental work in job/task analysis of ship personnel activities, evaluation of the equivalencies of time in grade and type of experience with simulator training, and development of an analytic tool to facilitate manning decisions.

3.3.1 Define Merchant Marine Job Requirements

The job activities of ship personnel are presently defined by the type of ship, the trade pattern, position within the hierarchy (e.g., licensed/unlicensed) and broad organizational distinctions (e.g., deck, engine and steward department). There appears to be relatively little formalized information available, either in industry or government, that specifies the job and task content of ship personnel. This leads to difficulty in understanding the impact of automation on ship human resource structure, the development of valid licensing exams, and in creating a personnel subsystem in which certain fundamental skills such as emergency response are redundant. In order to establish an adequate technical basis for such activities, it is necessary to conduct a job/task analysis of personnel activities. Prior work in shipboard job and task analysis (Denny, 1987; National Research Council, 1990) either focused on shipboard organizational concerns such as participative management, and indicated that more task detail would be useful. The principal product of job/task analysis will be an objective description of the job functions and tasks performed by the personnel on a range of commercial ships of typical concern to the Coast Guard (tankers, cargo ships and passenger ships). These descriptions will provide detailed information on both the job functions required of different ships, and the functions of individual personnel manning those positions. As such, the data will address issues of manning requirements and licensing. Further, they will provide the basis for training program development and for evaluating the potential for automating various tasks that are currently performed by humans. For a detailed description of the technical approach to this work refer to solution number 1 on page C-1 of Appendix C.

3.3.2 Simulator and Sea Time Equivalency

Current Coast Guard licensing regulations are based on the amount of time a mariner has spent in at-sea duty, and on the ability to pass written tests of knowledge. In an industry where it is likely that personnel will move from one type of ship to another, possibly involved in different routes and types of trade, the utility of simulator training increases greatly. By offering the ability to replicate the key performance features of particular ship types and situations, officers can gain experience in situationally-specific aspects of shiphandling without necessarily having firsthand experience. The handling characteristics and fidelity of simulators such as CAORF can thus enhance, and perhaps substitute for sea time. Unlike the airline industry (Caro, 1988), however, the Coast Guard does not

have well-specified equivalencies for substituting simulator training for sea time. The Code of Federal Regulations (46 CFR 10.304) states a general decision rule permitting combined training course and simulator work to substitute for "a maximum of 25 percent of the required service for any licensing transaction." The Coast Guard specifies sea time substitution for training courses on a case-by-case basis. In view of the potential utility of simulators for complementing licensing exams by means of proficiency checks, and for providing experience in situations not previously experienced by trainees (and perhaps not likely to be experienced even over an extended period), it would be beneficial to have a better mapping of ship simulator experience to the actual requirements of sea duty. The main product of this work will be an assessment of the state of the Coast Guard procedures for equating sea time and simulator experience in terms of the validity of the underlying assumptions in both regulations and training course content. Recommendations will be provided for improving both regulatory requirements, and training course content in order to provide more specific training objectives to be met by either sea time or simulator experience. For a detailed description of the technical approach to this work refer to solution number 2 on page C-4 of Appendix C.

3.3.3 Time in Grade and Type of Experience

Existing licensing regulations were implemented in 1989, and reduced the number of designations from 105 to 45. The system was implemented to eliminate trade and ship type distinctions. As a consequence, there are no license delineations based on the type or size of vessel (e.g, coastal tanker, VLCC or ULCC) or for tonnages above 1600 GT. The Coast Guard Tanker Safety Study Group (1989) acknowledged a potential problem with this system by stating, "no longer is a master of a small coastal tanker of 4000 DWT qualified in a practical sense to command an LNG, LASH, large containership or ULCC." Because the qualifications for operating various types of ships under different trade routes are not reflected in the licensing structure, there is a loss of quality control over the composition of ship human resources. While industry appears to self-regulate this issue, it would be desirable to have more formal information available to assist industry in ensuring a proper match between the experience of a particular officer, and potential assignments. Additionally, such information (e.g., a mapping of experience requirements for potential assignments to time in grade, with potential substitutions), would permit a better assessment of the manning structure of foreign flagged vessels. The results of this work will be a "skills transfer matrix" that will illustrate the degree to which training and experience required by law readily transfer to specific shipboard applications. By indicating the extent to which statutory requirements and operational requirements of jobs are mismatched, specific "job transfer functions" consisting of training enhancements can be developed. Individual officers lacking certain experience would follow the prescribed training transfer function, and then be ensured of possessing the requisite KSAs for a particular type of ship. Additionally, guidance documents for evaluating the qualifications of human resources aboard various types of foreign flagged vessels can be developed; this latter type of product will facilitate comparison of U.S.

and foreign manning standards, and permit a more objective evaluation of the safety of foreign flagged vessels entering U.S. waters. For a detailed description of the technical approach to this work refer to solution number 3 on page C-6 of Appendix C.

3.3.4 Automation Impact Manning Tool

Economic and technological changes, combined with outdated regulatory policies illustrate the need to develop a technical basis for manning levels. Technological innovations have led to unattended engine rooms, and the future promises further advances in navigation equipment that include electronic chart displays and integrated bridge designs. Along with technological advances, economic pressures continue to increase. Much of the economic pressure stems from foreign flagged ships that use lower manning levels, and less expensive seamen. The combination of increased technological sophistication and economic pressures have led some to question the manning policies specified by Coast Guard regulations, and economic viability of U.S. flag ships. At the same time the need to maintain safety makes officials hesitant to lower manning levels, without firm evidence that such a reduction would not reduce current safety standards. Driven by the need to reconcile technological advances with economic pressures and ship safety, the marine industry needs a method to determine the effect of modifying the human resources on board ships. Manning models offer a possible solution to this problem. For a detailed description of the technical approach to this work, refer to solution number 4 of page C-9 of Appendix C.

3.3.5 Summary

The principal objective of the Manning, Qualifications, and Licensing program area is to improve the procedures and data that current regulatory practices are based on. This will require applied research in job/task analysis and transfer of training, and development of a design-oriented solution in the form of an automation impact assessment tool.

3.4 AUTOMATION DESIGN APPROACHES PROGRAM AREA

New approaches to the design of automation need to be developed, so that human factors will be an integral part of system development. One of the issues associated with introducing automation in the maritime environment is the impact on the individual operator's ability to process information

3.4.1 Cognitive Impact of Automation

The automation problem has a number of associated issues beyond cognitive effects on individual operators, as well. Many activities aboard ships are complex, human resources-coordinated activities. Developing automation to facilitate these jobs (and to potentially alter the human resource structure), requires detailed information on the structure, timing and loading of tasks on individuals and teams as they perform a variety of operations at various phases of a voyage. Specific areas to be addressed include electronic navigation aids, workload during shipboard operations, alarm system design, information requirements for task performance, the workload of VTS operators, and training for new automated system.

Increasing levels of automation on board ships have led to human resource reductions, and alteration in how certain job functions are performed. In particular, automated systems offer the prospect of reducing physical workload and some of the sensing/control tasks previously performed by humans. They also place new demands on human cognitive processes, such as attention and memory. The basic question that needs to be addressed is the extent to which new automated systems that are being installed on ships, such as engine room alarm/monitoring and collision avoidance systems reduce error-prone repetitive tasks performed by humans, and the extent to which they place new and possibly greater demands on the limited capacity of human operators to process information. For a detailed description of the technical approach to this work refer to solution number 5 on page C-13 of Appendix C.

3.4.2 Training in Support of New Technologies

By increasing the level of automation on board ships, personnel have reported several problems and issues associated with the new technology. In general, the Coast Guard and industry recognize the need for more in-depth training related to operating, interpreting, and communicating information obtained from automated systems. Training for automated systems should provide the following: (1) a clear linkage between actions and processes used to perform in a training simulator and actions and processes required to operate and interpret data from automated systems on board ships; (2) clear guidance and procedures for using autopilots and procedures for communicating this information; (3) a more in-depth understanding of the capabilities of ARPA and ECDIS and knowledge of procedures for using all of its functions more effectively.

The questions that need to be addressed in a training evaluation are: (1) what type of training is needed and by which personnel meet immediate operations needs; and (2) what type of training is needed in the future to ensure correct implementation of new technologies? Results from an analysis of the immediate training needs related to automated equipment will yield the following products:

- Assessment of the match between current training on automated systems and training needs. If differences exist, recommendations will be provided for modifying the current training program(s).

- Identification of which personnel require training on automated systems. It is expected that more personnel actually require training on these systems than receive it.

Results from the job/task analysis results will be used to provide a broader review of training needs, including guidelines for industry training requirements, and data to facilitate determining Coast Guard approval of particular courses. This work will also consider the non-technical aspects of training, e.g., human resource-coordination skills. For a detailed description of the technical approach to this work refer to solution number 6 on page C-15 of Appendix C.

3.4.3 Workload: Bridge, Port Calls, and Cargo Activities

The complexity of bridge operations on large commercial ships can range from 4 to 5 persons, to 2 persons in U.S. flagged ships. These numbers reflect the requirements of transiting pilotage waters versus open sea conditions. With advances in automation, there are new possibilities to enhance the perceptual and control capabilities of bridge personnel, and a corresponding opportunity to reduce the numbers of personnel required for bridge watches in various conditions. The International Maritime Organization has established guidelines for conducting sea-trials of one-man bridge operations, and commercial manufacturers of navigation electronics offer their products as "meeting IMO standards" for one-man bridge operation. While the potential exists to complement human capabilities on bridge watch-standing, there is very little objective information concerning officer cognitive workload under the range of conditions that would be encountered in a typical voyage (e.g., piloted waters, unpiloted landfall conditions, unpiloted traffic situations, night operation, etc.). The existing experimental work evaluating one-man bridge concepts (Schuffel et al., 1990) has not provided detailed reports of the level of traffic used, nor introduced emergency conditions. Thus, in order to better understand the conditions in which reduced bridge manning may be appropriate, and how it should be supported by automation, more detailed information on bridge workload is required. The main product of this work will be a description of bridge operations on a generic ship that provides quantitative data on the workload and communication links for the various members of the bridge team in different scenarios. The quantitative information will be presented in terms of numbers and types of tasks, frequency, duration, and complexity. A byproduct of this work will be data concerning the instruments and information used to accomplish the tasks, thus providing a basis for developing automated systems such as piloting guides. Additionally, the data will provide a more objective basis for evaluating the performance of one-man bridge concepts, by suggesting ways in which rapid workload transitions can

be simulated. This latter information can be used to develop guidance for bridge team structure, and reliance on automation, under various navigational conditions.

Activities involved with port calls require special attention concerning the workload of ships' personnel. From the time the ship enters piloted waters until the ship is secured at the dock the personnel must attend to a wide range of tasks not included in routine sailing. During this time the ship must not only navigate more precisely, but it must also prepare and deploy lines for docking, and coordinate with VTS, a pilot, tugs and shore side personnel. These activities impose a variety of cognitive and physical demands on the ship personnel. The match between these demands and the technological and personnel resources influence the safety of the ship. Examining the cognitive and physical workload associated with port calls reveals the demands imposed on the human resources. This becomes particularly important as technology proliferates, lowering physical workload but possibly increasing cognitive workload. Workload descriptions will provide the basis for a quantitative analysis of the task demands with respect to the technological and personnel resources available during port calls. Comparing the task demands to the personnel and technological resources available will illustrate how technological innovations must integrate with the rest of the ship, as well as the shoreside personnel, to effectively support the entire port call scenario, as opposed to isolated aspects of it.

Cargo operations involve both shipboard and shoreside personnel in the loading or offloading of ship contents. In the case of bulk cargo ships, most of the work is done by shoreside personnel and equipment, although the chief mate ensures the quality of the operation. For liquid cargo, there is extensive involvement of ship personnel in starting pumps, monitoring tank levels and fill rates, communicating with shoreside personnel and checking for leakage. There is potential for human error in both bulk and liquid cargo operations; improperly loaded bulk cargo may shift and lead to critical imbalances; errors in transferring liquid cargo can lead to spills and potential explosions and environmental damage. To facilitate the development of automated cargo transfer systems, and to develop training and communication protocols that will reduce the potential for human error, quantitative information on the workload and operational sequence of cargo transfer activities is required. The analysis will provide the basis for development of company policies on shoreside support for cargo operations, guidance for team structure and job redesign (e.g., checklists and standardized communication protocols), and automation support. For a detailed description of the technical approach to this work refer to solution numbers 7-9 on pages C-18 through C-23 of Appendix C.

3.4.4 Design Guidelines

Navigation and Inspection Circular 89-04, Introduction to Human Factors Engineering, provides a reasonable tutorial on human factors in the first several pages. However, user interface development often proceeds somewhat independently from hull design, and in the case of retrofitted electronics, has no interaction with the overall ship design and construction process. Further, experience has shown that user interface development tends to be largely driven by tradition and the current capabilities of hardware/software. Thus, a more comprehensive NVIC addressing human factors would include a realistic design approach, and include more up to date information concerning user interface concepts, for both design and evaluation purposes. The objective requirement is a human factors NVIC that will be usable by a much wider range of people that is currently the case. First, by expanding topical coverage to a wider area than labeling, many more marine systems can benefit from the guidelines. Further, by presenting the guidelines within the context of a design cycle, with associated design-aiding tools, the reader can be a more active participant in the use of the material. By linking design characteristics to human performance capabilities, a rationale can be provided for regulatory requirements. The test and evaluation section can be used as the basis for developing better inspection procedures, and for providing testing labs with more explicit acceptance criteria. For a detailed description of the technical approach to this work refer to solution number 10 on page C-25 of Appendix C.

3.4.5 Alarm Systems

Alarm systems in the marine environment have been developed with little consideration of how they might best communicate crucial information to ship personnel. While the IMO resolution A.686(17) provides guidance concerning what systems should have alarms, as well as some general guidance concerning alarm location and type, this document does not provide sufficient guidance to ensure that the alarms provide the ship personnel with an integrated understanding of the situation. With the advent of unmanned engine rooms and advanced navigation technology, the number of alarms located on the ship's bridge will increase dramatically. In addition to the increased number of alarms, some alarms frequently activate in the absence of a problem leading operators to ignore or disable the alarms. These problems suggest that additional guidelines need to be developed so that alarms not only alert the ships personnel, but also guide them to mitigate a possible emergency. Work in this area will review the cognitive aspects of alarm design, to suggest ways to present operators with a more coherent picture of the state of the ship. The product will be a set of display guidelines adapted from other industries with high rates of alarm information transfer. For a detailed description of the technical approach to this work refer to solution number 11 on page C-28 of Appendix C.

3.4.6 Information Distribution

The distribution of information from shipboard equipment is an important consideration in operations. It is usually the case that data from equipment are presented in some form close to the location of that equipment, and not remotely represented. For example, cargo tank levels are shown in the control room of a tanker, but not in the bridge or engine room. However, certain operational procedures that involve the interaction of multiple departments may be facilitated by having data from equipment presented in more than one place. An example would be taking a cargo pump offline as certain tanks are filled; in some ship configurations this would involve verbal communication between the engine room (source of power for the pumps) and the control room (location of the data); accurate communication of such information is important in order to prevent overfills or pump burnouts. With the development of automated systems for many aspects of ship operation, there is the prospect of presenting task-relevant data at multiple workstations. The quick availability of information at multiple workstations will be increasingly important as manning is reduced. To effectively pursue this design approach, it is important to have an understanding of the information requirements of shipboard personnel during various routine, abnormal and emergency operations. The output of this work will be an information allocation of function matrix, which can be useful for determining how to support shipboard functions with computer-based automation. For a detailed description of the technical approach to this work refer to solution number 12 on page C-31 of Appendix C.

3.4.7 Electronic Navigation Aids

Electronic aids to navigation have reached a level of sophistication that may challenge the knowledge of the average user. For example, certain ARPA technologies are able to plot up to 32 targets simultaneously; this is well beyond the human span of perception or memory, particularly in a dynamic situation involving moving traffic and other obstacles. Additionally, a variety of functions are provided, which mariners report using only a subset of, perhaps because of training limitations or lack of understanding. Similarly, ECDIS type displays offer the prospect of enhanced information manipulation by means of electronically representing paper charts, as well as eliminating manual track keeping and other repetitive functions. However, recent research (Aertz, 1991) has shown that there are costs in terms of navigational performance associated with making mental rotations of electronic map displays to correspond to the ship-centered reference. This indicates that there is potential to lose "situational awareness" during operations involving altered track types on electronic map displays. Further, research with software systems having nested functions (Shneiderman, 1987) indicates that there is potential to become "lost in the system." Because of the potential for enhancing navigation capability, it is important to more fully understand the implications of sophisticated electronic display systems from the human performance standpoint, and to develop guidelines for design. Work in this area will involve the evaluation of several typical displays based on existing display design

approaches. The product will identify deficiencies in current designs, and present concepts and guidelines for future maritime displays. For a detailed description of the technical approach to this work refer to solution number 13 on page C-33 of Appendix C.

3.4.8 VTS Workload

A special case of automation-related human factors problems can be seen in the workload that VTS operators experience in monitoring ship traffic. This may affect performance either by reaching a level that exceeds their capacity, by dropping below a level that maintains their attention on the task, or by changing abruptly from low levels to high levels. Each of these instances has different consequences for performance and requires different human factors techniques to mitigate the effects on the performance of the operator. For example, monitoring as many 20 targets simultaneously exceeds the operator's span of apprehension, leading the operator to shed tasks, ignoring some ships to direct more attention to critical ships. On the other hand, if an operator has very few ships to track, other tasks may distract his attention. Finally, abrupt changes from low to high workload may lead to "cognitive tunnel vision" where the operator focuses on a single ship or task. With "cognitive tunnel vision" operators often fail to focus their attention on the most important aspect of the task, devoting attention to a ship many miles from shore as other ships go unobserved and pass dangerously close to each other. Examining the workload of VTS operators will reveal whether they suffer from overloading, underloading, or if the level of workload often shifts abruptly. The products of this work will be techniques to mitigate these effects, such as training needs, memory aides, and display modification. For a detailed description of the technical approach to this work refer to solution number 14 on page C-35 of Appendix C.

3.4.9 Summary

The work that is done under the Automation Design Approaches program area will facilitate the application of human factors principles and data to the development of new systems and regulations. A broad spectrum of activities involving user-interface evaluation, workload studies, requirements analysis, training evaluation and NVIC development will result in data and procedures that are useful at all stages of the system design and regulatory development process.

3.5 SAFETY METHODS AND DATA PROGRAM AREA

Decreasing the frequency of marine accidents depends on the existence of safety procedures and data that permit an understanding of the root causes of safety problems, provide design guidance on how to eliminate those problems, and inspection methods to ensure that specific safety criteria are met. This program area has a number of diverse requirements, including the development of better accident investigation and inspection methods, improved human factors root cause analysis methods, and development of procedures and criteria for spill contractors.

3.5.1 Investigations

As many as 80% of marine casualties involve human factors root causes. However, the MSM volume on casualty investigation contains one page of information on human factors. A Marine Investigation Module (MIN Mod) has just been released and focuses on defining a human error taxonomy that will provide a more detailed level of information. However, such a taxonomy will be more useful if there are complementary investigation tools to elicit information in a reliable, valid way. The MSM appears to focus primarily on administrative procedures, such as how to conduct a hearing and the form and contents of casualty reports. This volume needs to be supplemented with detailed descriptions of accident investigation techniques with a focus on eliciting human factors information. The product will be a set of investigative tools that will be included in the Marine Safety Volume on casualty investigation. The purpose of this set of tools is to help investigators gather valid and accurate human factors information. It is essential that these tools be compatible with the Marine Safety Manual and that they parallel and complement the proposed Marine Investigation Module (MIN Mod). For a detailed description of the technical approach to this work refer to solution number 15 on page C-39 of Appendix C.

3.5.2 Human Factors Inspection Procedures and Criteria

Aside from licensing, the inspection of vessels, offshore rigs, and shoreside facilities is the primary means the Coast Guard has for preventing marine casualties. The inspection process is used to determine whether vessels and facilities comply with regulations and guidelines to ensure the safety of our harbors and waterways. The inspection charter is being expanded to include human-related factors.

Human factors inspection criteria need to be developed, along with the appropriate tools, procedures, and training. The set of training, tools, procedures, and criteria developed must be usable not only by the Coast Guard, but also by third-party labs and shipping companies, who will become increasingly

responsible for inspections over the next few years. For a detailed description of the technical approach to this work refer to solution number 16 on page C-43 of Appendix C.

3.5.3 Spill Response Organization and Evaluation

The poor readiness of emergency pollution responders has resulted in heightened awareness of the importance of developing and maintaining emergency response teams in both the public and private sector. In response to this heightened concern, a number of cooperatives have been developed in various areas of the country, as well as a national organization (the Marine Spill Response Corporation). Additionally, the Coast Guard is in the process of developing district-based response teams to supplement the capability of the geographically distributed National Strike Force. It is already apparent that there is some confusion among the existing organizations regarding jurisdictions, magnitude of spill to be responded to, and how to cooperate in the event of a major spill. Further, the Coast Guard currently has no well-developed criteria or procedures for determining the readiness level of the cooperatives, or job descriptions established for its internal teams. This situation can be clarified by establishing guidelines on a national level for the capabilities of an emergency spill response cooperative, and by defining procedures for levels of activation, given spills of various magnitude. The focus of this work is to develop a common definition of emergency pollution response that can be used to implement and inspect emergency response organizations. For a detailed description of the technical approach to this work refer to solution number 17 on page C-44 of Appendix C.

3.5.4 Summary

Improvements in accident investigation, inspection procedures and spill response evaluation will converge on safety from two directions. First, by providing more comprehensive accident data , human factors root causes can be better identified. Then, by utilizing more focused evaluation/inspection tools, preventive means can be verified.

3.6 COMMUNICATIONS

The communications area involves both human-human communications, and communications in terms of other media, such as navigation markers or instructional procedures on how to accomplish a task. Improvements in these areas will result in better traffic management and adherence to technical and administrative procedures. The importance of these areas is indicated by the role of ambiguous

communications and procedural violations in the Exxon Valdez accident. Improvements required in this area include written procedures, aids-to-navigation and VTS communications.

3.6.1 Procedures: Technical and Organizational

Procedures underlie the performance of most routine tasks in shipboard operations, as in other technical areas. They establish a sequence of operations to be followed for correct performance of some task or function. It has been found in the analysis of human error in the nuclear and aviation industries that failure to follow procedures is related to later accidents (e.g., Chernobyl and the Chicago DC-10 accidents). The National Transportation Safety Board report on the Exxon Valdez accident included numerous examples of failure to follow prescribed procedures. Analysis of procedural violations in the nuclear industry suggests that there are three principal reasons why procedures are not followed: (1) personnel think they know the procedure and do not need to make reference to it, (2) the procedure is unusable because of poor quality construction, and (3) personnel do not believe the procedure is applicable, or that certain steps are not applicable. There is little information available concerning the relative use of procedures in the maritime industries in terms of the content, frequency of use and quality of construction. In order to ensure better use of procedures for accomplishing various tasks, and to understand the best way to package these procedures (e.g., written versus computerized job aids), an evaluation of procedural use and utility in selected maritime operations should be conducted. The evaluation of procedures will yield information concerning the extent to which written procedures for maritime jobs are properly designed and presented. Deficiencies that are discerned will result in recommendations for improvement; procedure guidelines from other industries may be adapted for incorporation into a NVIC. Interview and survey data will reflect the general attitude toward the utility of written procedures, and provide an indication of broad areas warranting improvement. A survey/call-back study would provide useful detail on how work situations and organizational policies affect the motivation to follow procedures. These results will be used to develop guidelines for application to written procedures throughout the maritime industry. For a detailed description of the technical approach to this work refer to solution number 18 on page C-48 of Appendix C.

3.6.2 Aids to Navigation

The Coast Guard designs its aids-to-navigation system to ensure the safe and expeditious passage of vessels in US waters. Many of the design principles governing the mix of aids, their placement in a waterway, and the selection of the hardware are driven by engineering considerations, often without regard to human performance and human-system interaction issues. This approach to aid system design sometimes yields systems that may be inadequate, causing mariners to spend excessive amounts

of time acquiring the needed information, which interferes with navigating or driving their vessel. In addition, sometimes inconsistencies in the strategies used for marking waterways may contribute to navigation errors. The problem to be addressed is how one ensures that an aids-to-navigation system is optimized for the human operator. The three major problem areas to be addressed are: (1) what should be the proper mix of aids to navigation, both now and as we head into the twenty-first century; (2) how can we improve the design of waterways with respect to the placement of aids; and (3) how can we increase the conspicuity of short-range aids? For a detailed description of the technical approach to this work, refer to solution number 19 on page C-50 of Appendix C.

3.6.3 Dissemination of Information to Mariners

The Coast Guard disseminates information to mariners in several ways. For example, there are Navigation and Vessel Inspection Circulars, navigational charts in various periodicals, chart updates and navigation information broadcast over the radio. This task will evaluate the media used to disseminate information and recommend changes, if any, to make the information more easily available to the users, by presenting it in different forms or providing emphasis where needed. For a detailed description of the technical approach to this work refer to solution number 20 on page C-53 of Appendix C.

3.6.4 VTS Communications

Communication between commercial vessels and the Vessel Traffic System is required by the Code of Federal Regulations (Part 33). Vessels are required to report 15 minutes prior to departure or arrival within a controlled area, and must monitor the appropriate communications channels. There is general agreement within both VTS and commercial vessel personnel that communications are not optimal; the issues involved include required response to VTS initiated communication during critical maneuvering, an apparent lack of responsiveness of ships to VTS communication, uncertainty on the part of the VTS as to which person they are talking to, and VTS requests for information from ships (such as barometric pressure readings) that interfere with ongoing tasks. While these issues have been articulated, there is also general agreement that the system functions well. Thus, there appears to be a need for more structured communication protocols, i.e., general guidelines for who should contact VTS from the ship, the acknowledgements of communications, and the type and extent of information transfer. Evaluation of user needs and alternative communication approaches will result in a set of guidelines for communication between VTS and commercial ships. For a detailed description of the technical approach to this work refer to solution number 21 on page C-54 of Appendix C.

3.6.5 Summary

The primary objective of work in this program area is to improve the transfer of information to human operators. Thus, work in procedures, aids-to-navigation, and VTS communications will lead to better methods of conveying specialized technical information.

3.7 ORGANIZATIONAL PRACTICES PROGRAM AREA

While it is possible to trace most safety-related problems to a human root cause, it is often the case that these root causes are induced or exacerbated by organizational factors. The organizational program area identifies several areas in which work can be conducted that should result in better management practices with respect to work scheduling, and in developing a Coast Guard organization that can facilitate the application of human factors in a wide number of areas, both internally and externally.

3.7.1 USCG Organization

The U.S. Coast Guard is organized along functional lines, such as Law Enforcement, Marine Safety and Engineering. Human factors issues tend to encompass the concerns of numerous functional organizations. For example, human factors concerns are evident in the design of aids to navigation, commercial ship electronics, and vessel traffic systems. It is unrealistic to expect that each functional office within the Coast Guard will employ a trained human factors specialist to ensure that the human operator is considered in design and regulation. Further, because of the importance of setting internationally agreed upon standards, it is important that human factors safety issues be developed in conjunction with the efforts of the International Maritime Organization. While the Human Factors Coordinating Committee of the Marine Safety Office has been empaneled, there is no focal point for human factors implementation across the diverse Coast Guard offices (although the R&D Center is the focal point for human factors research). In order to determine the best organizational structure for human factors implementation, an organizational design study should be undertaken to define the mission, structure and location of a dedicated headquarters human factors function. Previous contract work (AIM, 1989) has suggested the need for such a function, but did not provide sufficient specification to actually establish the activity. The primary product of work in this area will be a set of recommendations on where and how to implement a human factors program office within USCG HQ. These recommendations will be based on the findings of an HQ and district organizational survey, and the resulting model illustrating the processes, systems and mechanisms used by offices, divisions and branches that could benefit from human factors support. Further, the "lessons learned" from other large government and industrial organizations in implementing human factors will provide

a basis for understanding the practical aspects of implementation. For a detailed description of the technical approach to this work refer to solution number 22 on page C-56 of Appendix C.

3.7.2 Ship Personnel Fatigue and Organizational Policy

There are two areas in which organizational solutions would be warranted related to personnel fatigue: These include work schedule and vacation policies, and suggestions for alternate watchkeeping schedules, either through compressed watch times, or rotating across sea tours to ease the impacts of sleep times. OPA '90 specifies work hour limitations for personnel aboard oil tankers to be no more than 15 hours per 24, and 36 per 72. These work hour limitations assume that fatigue is primarily a "phasic" effect, i.e., fatigue is a short-term phenomenon that will diminish with a brief but sufficient rest period. The rule also assumes that all personnel on board will experience identical amounts of fatigue. However, evidence is accumulating that long job durations lead to "burnout" and lack of attention to performance, despite having adequate rest during a particular circadian period. Additionally, some trade routes such as the Alaska oil routes, entail chronically foul weather, which results in extreme physical fatigue because of sleep loss and balance compensation. Little is known about what may constitute a sufficient period of recovery under these conditions. Finally, the work limitations currently imposed by OPA '90 assume that each position on board the ship results in similar fatigue levels and recovery period requirements. This assumption is very likely to be inaccurate, since there are a variety of different watch-standing requirements, some of which permit a full eight hours of sleep during the night, and others which do not. The intent of this work is to quantify the fatigue problem while controlling for other variables that might influence it, such as social structure and personnel rotation.

The work rule of OPA '90 has resulted in various responses among the major oil shipping companies; one company appears to handle the work rule limitation by using a shoreside cargo mate (also subject to the rule) to assist in cargo operations. Other companies have added another licensed crew member, or request riding relief personnel based on predicted voyage profiles. Two years have passed since the enactment of this rule, and it would be desirable to conduct an assessment of its effectiveness in reducing fatigue. In particular, it would be useful to know if limiting the work hours has resulted in more sleep time and thus less fatigue, or if it simply results in less work time, without corresponding rest. The impending use of fitness-for-duty tests with shipboard personnel is related to this issue, since fatigue is a major factor in performance on such tests. Further, the applicability of more extensive shoreside support in tanker operations may be an alternative solution to work-hour limitations, if such limitations are found to be ineffective in reducing fatigue. The products of this work will be recommendations concerning alternate watchkeeping schedules, vacation policies, and shoreside support. For a detailed description of the technical approach to this work refer to solution numbers 23 and 24 on pages C-59 and C-62 of Appendix C.

3.7.3 Summary

Work carried out under the organizational practices program area will lead to more effective integration of human factors across a broad spectrum of Coast Guard programs. Further, by quantifying the impact of industrial policies on ship personnel, alternative practices can be developed.

IV. PLAN FOR MARITIME HUMAN FACTORS

The previous chapters have outlined the historical background of maritime human factors and planning for human factors in other industries, the methods for identifying critical human factors issues in maritime applications, and the elements of a human factors program necessary to address these issues. This chapter discusses initiating and executing the elements of a human factors program, in terms of the priorities, interrelationships and timing of tasks, and the role of coordination between USCG HQ, industry and the technical personnel carrying out the work.

The fundamental product of the various program areas discussed in Chapter 3 is information; i.e., human factors work will result in data and principles that will facilitate the development of hardware and software by industry (or the specification of procurements by the Coast Guard), and the development or interpretation of regulations to enhance the marine safety mission. As discussed in Chapter 1, a human factors technical basis for evaluation and decision making in carrying out the USCG Marine Safety Mission does not exist in a useful form; the purpose of the work proposed in the strategic plan is to generate the necessary information for this technical basis through applied research and design oriented solutions. Since the purpose of this plan is to guide research and development activities, it should be periodically reviewed and updated to reflect progress.

4.1 PROGRAM AREA RELATIONSHIPS AND TIMING

As described in Chapter 3, there are a number of areas within each human factors program area that need to be addressed. From the standpoint of sequencing the work, it is important to consider the relationships between the work areas within and between program areas. These relationships are depicted graphically, in Gantt chart form, in Figure 4. This figure illustrates the prospective time required for each work activity within a program area. Additionally, the work conducted under two of the program areas will contribute directly to the development of quantitative manning models that are more fully specified in Task B (Lee and Sanquist, 1992) of this effort. This schedule should be viewed as tentative, based on the current understanding of the work required. Further, as shown in Figure 4, projects are shown relative to an arbitrary start time, indicating that projects in different program areas can have different start times. While a two year period is shown for most of the work specified, this is not a requirement and will more likely require 3 - 5 years to accomplish. Instead, this plan should be viewed as one way of accomplishing the work that needs to be done; within the framework provided there is opportunity for combining certain program area tasks, and for expanding or contracting efforts based on resource and time constraints. The following paragraphs describe the strategy in more detail.

Each of the program areas contains what might be considered critical tasks that should be performed prior to other work being done. Some of the critical tasks feed the activities of subsequent tasks, while others are necessary simply to get the human factors program organized and under way.

In the Manning, Qualifications and Licensing program area, the critical task is the definition of merchant marine job requirements through a comprehensive job/task analysis. All subsequent activities involving evaluating simulator equivalency with sea time, linking time in grade with type of experience, and developing an automation impact assessment tool depend on data obtained through JTA. Thus, the JTA is shown as being initiated in the first month of program efforts; an early output of this work will be useful for work specified in Task B (Lee and Sanquist, 1992), concerning the development of a manning model to evaluate shipboard emergency response capability. Further out in time, generic job descriptions will serve as inputs to more detailed analyses of the job requirements on specific types of ships. Approximately 12 months after the JTA has begun, it would be appropriate to initiate work on simulator and sea time equivalency. By that time, sufficient data concerning training courses and practices will exist to review the USCG approval process for simulator course substitution. As the JTA moves forward in time, more specific training requirements for jobs will become apparent, and will provide input to the training evaluation conducted in the Automation Design Approaches program area.

The sequencing of tasks in the Manning, Qualifications and Licensing program area is designed so that the task area involving Development of an Automation Impact Assessment Method will receive input from them. This latter task will yield tools for ensuring proper manning levels based on task requirements; to develop such a tool requires inputs from other tasks concerning specific job/task requirements and their allocation to personnel. The specific requirements for developing these models are discussed in detail in Task B of this effort (Lee and Sanquist, 1992). Many of the tasks specified in this plan will provide data that are critical for the development of manning models.

Automation Design Approaches involves a number of related task activities; two of the critical tasks are Cognitive Analysis and Workload Analysis. The cognitive analysis will provide inputs for subsequent evaluations of the user interface of automation, which can provide a basis for defining scenarios for workload analysis of bridge team performance, as shown in Figure 4. The workload analysis is shown as a 24 month process, which is reasonable in view of the complexity of the operations to be evaluated. The timing of the workload analysis is designed to provide inputs to the Manning, Qualifications and Licensing program area for the development of the automation impact assessment tool; this input will be in the form of task lists, task times and frequencies, and quantitative PSFs. Additionally, the workload analysis will provide inputs to a manning model that entails definition of work hour requirements for a variety of shipboard jobs.

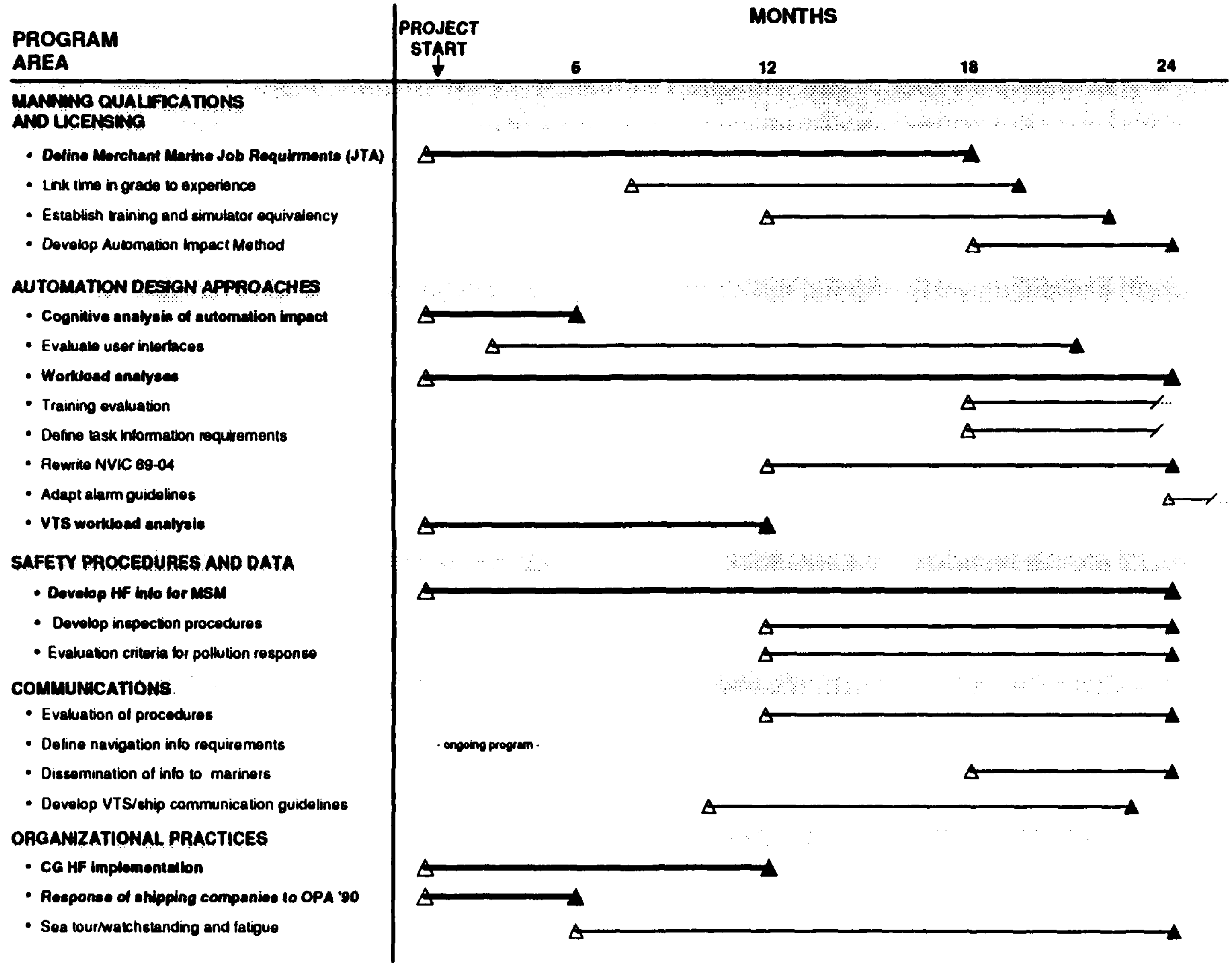

Figure 4

Gantt Chart for Human Factors Program Areas and Project Tasks. **(Critical Tasks are shown in bold print with thick lines.)**

Other elements within the Automation Design Approaches program area include training evaluation for automation, definition of task information requirements, rewriting NVIC 89-04 and adapting alarm guidelines for maritime usage. Training evaluation will receive a direct input from the Manning, Qualifications and Licensing element in the form of training requirements that are identified by JTA and related activities. Thus, this task is shown as starting after the JTA is completed. Similarly, the definition of task information requirements will need inputs from the workload analysis and JTA, and thus, starts later in time. Rewriting NVIC 89-04 is a job that should derive benefit from 12 months of work on specific human factors issues from multiple tasks. These tasks will provide many useful examples of how to design (or not to design) systems from the human factors standpoint. Similarly, the alarm guidelines task will benefit from evaluation of many user interface examples in the preceding months.

Evaluation of VTS workload is the final task within the Automation Design Approach program area. This task is shown as critical because new equipment is being developed for VTS; the development of this system should be informed by a human factors requirements analysis.

Within the Safety Methods Data and program area, the critical task shown is the development of human factors information for the Marine Safety Manual on accident investigations. This task is particularly important to accomplish quickly, so that field investigators will have appropriate tools at their disposal to better identify human factors root causes. This information will, in turn, feed back to many ongoing design and legislative activities. Related tasks in this program area include developing better vessel and shoreside inspection criteria and procedures, and criteria for evaluating pollution response contractors. These tasks will need to incorporate job function-related information, and so need to be placed further out in time.

In the communications area, all tasks require input from work conducted in other program areas. For example, the evaluation of procedures must be based on knowledge of job functions and the extent to which procedures are used (i.e., inputs from JTA and workload analysis). Similarly, communications guidelines for VTS must be based on knowledge of task requirements and workload assessed in another task.

The Organizational Practices program area contains two critical tasks: implementing human factors in the Coast Guard, and evaluating the response of shipping companies to OPA '90 work hour limitations. The former task will be a structured process to define the range of human factors activities within the USCG, and to develop a properly staffed program office. This task is critically important in view of the complexity and breadth of the work defined in this plan. Similarly, evaluating the impact of the OPA '90 work rules will provide important cost/benefit information for use in determining the impacts of other regulations affecting ship personnel activities. Finally, the output of the OPA '90 evaluation will provide an initial understanding of current work practices that

will facilitate a more detailed evaluation of one of the merchant marine's most frequently cited problems: fatigue.

4.2 RESOURCES

Resource estimates to carry out the work discussed above have been provided in terms of staff years in Appendix C, for each specific project. The total staff year requirement is 24.16. For the seven critical tasks, the total staff year requirement is 10.2; this involves 6.5 staff years in the first year of the plan, and 3.7 staff years in the second 12 month period. The total staff year requirements for each of the plan program areas are as follows: Manning, Qualifications, and Licensing - 5.7; Automation Design Approaches - 8.1; Safety Methods and Data - 5.6; Communications - 2.2 (this area has two projects in which resource requirements remain to be determined); Organizational Practices - 3.0.

4.3 HUMAN FACTORS COORDINATING COMMITTEE

The Human Factors Coordinating Committee (HFCC) will serve an integral role in the design and execution of the work described in this plan. The HFCC in conjunction with the human factors personnel from R&DC will provide continuing guidance for carrying out specific human factors solutions. Such guidance would include (but not be limited to) identifying pending regulatory action that could be affected by project results, linking the structure of tasks to planned or ongoing administrative initiatives, focusing the gathering of task-related information to facilitate the development of an internal product, such as a NVIC or guidance document, and providing input on potentially useful casualty or investigation information.

At present, the HFCC is composed primarily of members of the Office of M, since human factors is viewed primarily as a marine safety function. While this is accurate, it is important to recognize that many developments outside the purview of the office of M will have human factors implications or requirements for design. Other agencies such as the FAA have structured their HFCCs to include representatives from all major agency divisions; the purpose of such a structure is to ensure that coordination actually takes place. In approaching the work proposed in this plan, it would be desirable to expand the scope of representation of the HFCC to ensure all relevant offices within the Coast Guard are represented.

A primary function of the expanded HFCC will be to incorporate the results of the work described in this plan into a human factors technical basis for regulation. The general process for the marine safety mission shown in Figure 1 needs to have a strong technical basis. A key element of the strategy of

this plan is to provide an explicit technical basis for evaluating and controlling maritime safety problems.

4.4 INDUSTRY RELATIONSHIPS

Any major developmental initiative, such as the Maritime Human Factors Plan, should take place with the close involvement of industry. The FAA, for example, based much of their plan on work that had been done by the Air Transport Association, which is an industry-based government relations and standard setting group. The work proposed in this plan should be critiqued by the marine industry, and suggested refinements incorporated. A potentially appropriate group for providing the industry perspective would be the International Ship Managers Association (ISMA), the Marine Transportation Committee of the American Petroleum Institute, the American Institute of Merchant Shipping, union associates and the Maritime Administration. Informal contacts with industrial personnel suggest that there is great concern over the human factor in shipping, and that joint industry-government efforts to deal with these issues would be desirable.

4.5 SUMMARY

This chapter outlines a strategy, timeline and resources for accomplishing the work necessary to build a human factors technical basis for the marine safety mission. The timeline is based on seven critical tasks in the five program areas, and are sequenced in such a way as to provide necessary input for subsequent tasks. The total resource requirement of the human factors plan is 24.16 staff years.

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APPENDIX A

Structured Interview Protocol and STAR Model

This appendix contains a list of the questions used for the structured interviews with Coast Guard and industry personnel. The interview protocol shown on the next page was used to guide discussion on the basis of the Shipping Technologies and Resources (STAR) model, described in the following pages. Questions were modified appropriately for industrial respondents to focus on design and training issues, rather than regulatory and guidance matters.

QUESTIONS FOR HUMAN FACTORS PLANNING INTERVIEWS

The purpose of this interview is to obtain your input on the human factors issues faced by the Coast Guard and shipping industry. The results will be incorporated into a Coast Guard Plan for Human Factors. Attached is a framework for discussion that we would appreciate your comments on; we also believe it will stimulate ideas about human factors issues in various aspects of the maritime environment.

We believe the interview will take approximately 60 - 90 minutes, in which we would like to discuss the following general questions:

1. Please describe the mission of your branch or office, from the standpoint of its regulatory role and information dissemination function, e.g., what aspects of the shipping industry are affected and how is the policy implemented?

2. Do you see specific areas in which there are problems related to human performance, safety or technical systems operated by humans that fall into the purview of your branch or office?

3. How have the human performance problems manifested themselves? Increased accidents, reports, public concern or inquiries to this office?

4. Are there areas related to human performance and safety of concern to your office in which the US is not commensurate with IMO standards?

5. What types of solutions do you envision for the problems described, e.g., engineering, procedural, regulatory?

Please consider these questions in terms of your experience with your branch or office, and in relation to the model described in the attached pages. We look forward to meeting with you. Thank you for your cooperation.

Human factors can be conceptualized within the maritime environment in terms of the STAR model: Shipping Technologies and Resources. These technologies and resources can be considered as integral elements of the maritime environment. There are five domains that involve significant human interaction, as shown below:

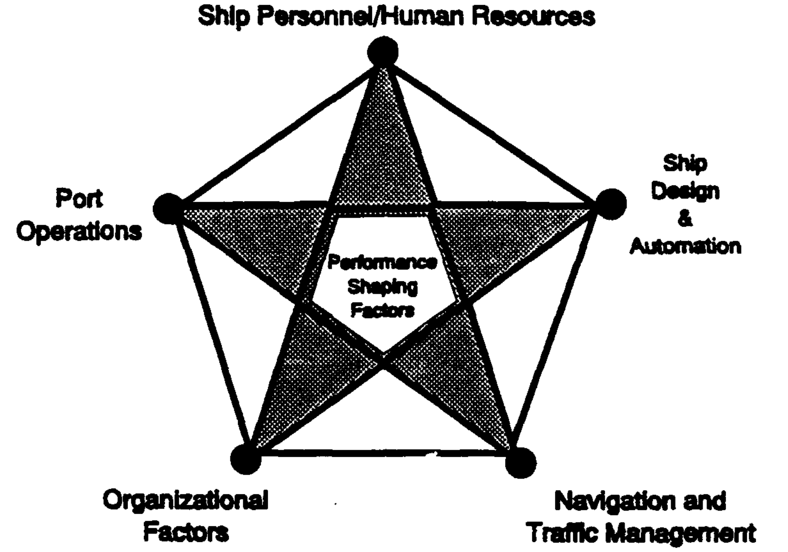

Figure A-1. Shipping Technologies and Resources (STAR) Model

As shown in the model, the five domains are interconnected, which is appropriate, given the multi-faceted nature of the shipping industry. All of these domains will be affected by various Human Performance Shaping Factors (PSFs) as shown by the central area of the STAR. These include such factors as **workload levels, fatigue, and level of knowledge.** This section summarizes definitions of these domains, lists a number of components of each, and provides illustrative examples of human factors issues in each domain.

Domain Definition

Crew Systems/Human Resources

The most obvious domain of human involvement is that of ship personnel. The ship personnel operate both on an individual level of discrete task performance, and at more aggregate levels of team and whole human resources performance. The concept of shipboard teams is being used more frequently

on commercial vessels, and so there is a relationship to organizational factors. The primary aspects of the human resource system include:

- Manning scales and methods
- Training, qualifications and licensing
- Emergency response and pollution prevention
- Fitness for duty
- Bridge team resource management

Two human factors issues associated with the human resource system include transfer of training, and fatigue. Transfer of training refers to the ability of personnel who are highly familiar with one type of ship and its systems (e.g., a container ship) to easily transition to working on a different type of ship (e.g., a tanker). Sometimes, there is **negative knowledge transfer**, in which previous knowledge interferes with the ability to perform tasks in a new environment. This may have to do with variations in company procedures, type of equipment, and specific duties. **Fatigue** results from insufficient rest periods, and may be both short-term (e.g., following port operations), and long-term (near the end of a tour of duty with extensive sleep disruption).

Ship Design and Automation

This domain is primarily concerned with the technologies used aboard ships, and the human factors issues associated with their use, such as understanding of automation, training, and safety. The following taxonomy provides a basis for identifying specific human factors issues:

Type of Vessel

- cargo
- passenger
- fishing
- tanker
- Coast Guard

Systems Automation

- steering
- integrated bridge
- mooring
- anchoring
- navigation electronics
- communication
- engine room
- cargo handling

Crew Accommodations

- living
- working
- recreation

A specific human factors issue associated with ship design is the **understanding of automated systems** by the ship personnel. For example, it has been reported that the capability of various electronic navigation devices are underutilized because of uncertainties on the part of the operators as to how the equipment works. More dangerous would be situations in which operators make **mode errors**, because they mistakenly identify the equipment mode, e.g., autopilot on or off.

Navigation and Traffic Management

Ships travel in open seas and in congested waters; this domain is concerned with human factors issues in both conditions. Elements of Navigation and Traffic management include:

Vessel Traffic System

- role in directing traffic
- design of VTS workstations
- human machine interface

Electronic Chart Display Systems

- usability
- role in situation awareness
- human machine interface

Waterway Design

- environmental influences
- marker types and placement
- physical dimensions

Piloting

- pilot/master interaction
- communications with tugs
- familiarity with vessels

Communications Between Ships

Rules of the Road

A general human factors issue associated with Navigation and Traffic Management include the **human ability to perceive and use information from electronic displays.** Both VTS and ECDIS systems present an electronic image to an operator, who is required to make a continuous set of decisions based upon that information. An improperly designed display can lead to **confusion about the meaning of information, underutilization of equipment, and interpretation errors.**

Port Operations

The domain of Port Operations is considered to be one of the most work intensive phases of a commercial ship voyage. Aspects of this domain include:

- Alternative support schemes for cargo operations
- Docking and undocking
- Frequency of port calls
- Shore support system and equipment

A frequently mentioned human factors issue in Port Operations concerns the issue of **physical and mental workload** of key ship personnel, for example the chief mate. Tankers require many hours to complete cargo operations; the new OPA '90 work rules limit the time that the people can spend on these activities, leading to potential discontinuities and opportunities for human error.

Organizational Factors

This domain refers to the policies and procedures of both the shipping industry and the Coast Guard, as they affect the performance of the ship personnel.

- Manning policies and union relations
- Scheduling and work rules
- Administrative requirements placed on human resources
- Safety training programs
- Maintenance policy
- Regulations
- Ship/Shore responsibilities and reporting relationships

A human factors issue that is influenced by organizational variables is that of **skill development for emergency response** in the case of groundings or collisions. Current organizational policies stress prevention; it is possible that greater emphasis can be placed on emergency response drills and pollution mitigation activities.

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APPENDIX B

Individual Human Factors Issues

This table contains the 68 individual issues identified during interviews with USCG and industry personnel, and extracted from the general human factors literature. The issues are presented in terms of their technical domain from the STAR model (see Appendix A), and an indication provided as to the principal solution objective related to that issue. The solution numbers are provided as an index to Appendix C, which contains descriptions of specific technical approaches.

Table B.1. Individual Human Factors Issues, and Their Classification by Technical Domain, Solution Objective, and Solution Numbers		
	Solution Objective	Solution Number(s)
Crew Systems/Human Resources		
1. Regulations specify personnel requirements without consideration of operational task demands.	M	1
2. External validation with respect to operational task demands of industry criteria for staffing ships does not exist.	M	1
3. The relationship of simulator training to seafaring experience as a surrogate for establishing critical knowledge and skills is poorly understood.	M	2
4. Inadequate training on new technologies installed aboard ships.	A	6
5. Current licensing exams focus on "classical" technologies and skills, without consideration of current task demands imposed by more modern automated systems.	M	1, 4
6. Data on ship personnel job/task activities for purposes of licensing exam development and manning decisions not available to CG in useful form.	M	1, 4
7. Licensing regulations are based on "time-in-grade" experience, without linkage to the type of experience (e.g., type of ship); as a consequence, licenses do not necessarily reflect qualifications necessary for meeting operational task demands. Industry tries to self-regulate this issue.	M	3
8. Port calls place excessive administrative and operational workload on master and chief mate of cargo ships; use of a relief or additional riding crew member may reduce these burdens (as on cruise ships); potential job expansion for other ship human resources.	M	1, 4, 8
9. Need guidance for use of autopilots and unattended engine rooms, in terms of procedures, communications, and feedback from equipment.	M	1, 4, 12

M = Manning, Qualifications and Licensing
A = Automation
S = Safety Procedures and Data
C = Communications
O = Organizational Practices

Table B.1. Individual Human Factors Issues, and Their Classification by Technical Domain, Solution Objective, and Solution Numbers		
	Solution Objective	**Solution Number(s)**
10. Need guidance for use of 2nd licensed officer on bridge, in terms of workload and operational task demands.	M	1, 4
11. Mismatch between certification and training for dock operators.	M	1
12. Lack of criteria for comparing manning decisions for US and foreign flagged vessels.	M	3, 4
13. Need to determine fitness for duty criteria under which personnel should be relieved by other personnel.	M	1, 7-9
14. Need guidance for use of background data in mariner licensing, e.g., alcohol use, driver records, criminal records.	M	1
15. Downsizing of human resources leads to lower aggregate skill levels, which may adversely affect routine and emergency operations, due to relative lack of experience with manual controls, and fewer people available.	M	4
16. Acute and chronic fatigue affects mariner ability to work safely and effectively.	O	23, 24
Port Operations		
17. Lack of criteria for composition of emergency pollution response capabilities with respect to training, procedures, equipment and certification.	S	17
18. Interface between equipment and personnel in cargo transfer operations is a "weak link" leading to spills, due to poor monitoring and communications breakdowns.	A	9, 12
19. Marine vapor control systems can overwhelm dock operators with information.	A	9
20. Need system to rate pollution contractor ability to respond.	S	17

M = Manning, Qualifications and Licensing
A = Automation
S = Safety Procedures and Data
C = Communications
O = Organizational Practices

Table B.1. Individual Human Factors Issues, and Their Classification by Technical Domain, Solution Objective, and Solution Numbers

	Solution Objective	Solution Number(s)
Navigation and Traffic Management		
21. CG disseminates a large volume of information in a variety of ways, e.g., navigation status on marine radio, bulletin boards, chart updates via periodicals, etc. There is uncertainty as to how mariners access and use this information.	C	20
22. Implementation of differential GPS will increase accuracy in coastal areas, leading to potential overreliance (e.g., "risky shiphandling") in hazardous situations.	A	7, 4
23. Lack of knowledge as to how ship human resources allocate time to administrative duties associated with CG information stream in contrast to shipboard operations.	C	20
24. Markers are used inconsistently, e.g., RACONs (USCG) and red-green buoys (international).	C	19
25. Aids-to-Navigation focus has been principally on the transmitter, rather than human receiver. Problem areas developing in visual conspicuity associated with urban backlighting and interpretation of signals.	C	19
26. Engineering models for channel/waterway design exist, but have not been validated with human performance data.	A	19
27. Lack of criteria for determining when VTS should provide explicit direction to vessels.	C	21
28. Communication between VTS and vessels is not well-defined in terms of roles on board ships, and frequency of contact.	C	21
29. Lack of coordinated communication between pilots and tugs in congested waterways in terms of visibility of obstructions.	A	7, 8

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Table B.1. Individual Human Factors Issues, and Their Classification by Technical Domain, Solution Objective, and Solution Numbers		
	Solution Objective	Solution Number(s)
30. Number of ships to be tracked by individual VTS operator may exceed attentional capacity.	A	14
Ship Design and Automation		
31. Operating instructions and procedures are often missing or inadequate.	C	18
32. Guidance needed for incorporating human factors in design, and for introducing and training personnel on automated systems.	A	10, 6
33. Lack of human factors criteria for overfill devices on tank vessels.	A	10, 9
34. Lack of knowledge about relationship between personnel accommodations and personnel fatigue and motivation.	O M	23 1
35. ARPA and ECDIS type technologies have many more functions than the average operator understands or uses effectively.	A	5, 13
36. Reliability of bridge fire alarm panel is poor, leading people to deactivate.	A	11
37. New automated technologies may impose increased cognitive demands on ship human resources (e.g. ECDIS, voyage data recorders, ARPAs, etc.)	A	5, 13
38. IMO code on alarms and indicators does not specify how or where information should be presented.	A	11
39. Ship personnel do not trust automated navigation systems because of legal incentives to use all available means for safe control of the ship.	A	13, 9
40. Automation is traditionally implemented in terms of job reduction, without consideration of changes to the structure of the human resources and changes in job content.	M	1, 4, 5
41. Need human factors analysis of one-man bridge concept to determine safety implications (e.g., one-man vs. two-man watch).	M	7, 9

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Table B.1. Individual Human Factors Issues, and Their Classification by Technical Domain, Solution Objective, and Solution Numbers		
	Solution Objective	**Solution Number(s)**
42. Automation can result in displays of information that are not available to all human resources who may need it, e.g., bridge and engine room. Need to define role of technology in communicating information between ship personnel and between ship personnel and ship systems.	A	12
43. International code on ship design should include human factors.	O	22
44. Cost-benefit analysis of technology introduction would be useful.	O	22
Organizational		
45. Length of sea tours is nominally scheduled at certain durations, but can extend unpredictably to longer durations, affecting fatigue and lifestyle of mariners.	O	23
46. Prior to OPA '90, it was more common for shipboard personnel to cover each other's watch, particularly in port, in order to break the routine. Current work practices preclude this.	O	24
USCG Internal		
47. Optimal user interfaces for access to large CG databases need to be defined (e.g., MSIS, Marine Safety Network, Vessel Inspection and Documentation Network).	O	22, 13
48. GT Life Cycle Management manual should incorporate human factors guidance for acquisition and development, including consistent user interfaces and methods for automating manual procedures. Style guides need to be consistent across applications.	O	22
49. Need better feedback from test users for BTOS management system.	O	22, 13
50. System managers should be trained in ergonomics, since their jobs involve configuring workstations.	O	22

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Table B.1. Individual Human Factors Issues, and Their Classification by Technical Domain, Solution Objective, and Solution Numbers		
	Solution Objective	**Solution Number(s)**
51. New casualty database system may impose additional data entry workload on officers, and could affect the completeness and accuracy of results.	S	15
52. Need to evaluate potential consequences of incomplete accident reports.	S	15
53. Need to define KSAs for CG personnel to participate in district-specific oil spill response groups.	S	17
54. USCG needs to develop procurement and design oversight approach involving human-system integration.	O	22
55. Linkage of casualty database to regulations in order to document effect of violations.	S	15
56. Training and/or tools are needed to ensure consistency in applying human factors in casualty investigations.	S	15
57. Human factors criteria for inspections of facilities and shoreside operations need to be developed to assist expanded inspection charter.	S	16
58. Human factors criteria need to be provided to third party labs to evaluate equipment for CG.	S	16
59. NVIC 169 does not consider human-automation interaction.	S	4, 5, 10
60. NVIC 89-04 difficult to apply because of emphasis on low level human factors design details, such as labeling.	A	10
61. Casualty investigations do not necessarily lead to identification of root cause. Need to determine locus of information breakdown, i.e., investigation process (not asking right questions), data coding procedures, data extraction procedures, etc. Suggestion that issues of design, operations, maintenance and past CG inspections need to be addressed.	S	15

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Table B.1. Individual Human Factors Issues, and Their Classification by Technical Domain, Solution Objective, and Solution Numbers		
	Solution Objective	**Solution Number(s)**
62. Self inspection of ships and offshore rigs will take place in the future and inspection guidelines that incorporate human factors need to be developed.	S	16
63. Inspections are based on compliance with minimum standards, rather than assessments of operational effectiveness or safety potential.	S	16
64. MTH development of NVICs lags industry development; NVICs based on operating experience.	O	22
65. Need tool to determine human factors costs and benefits associated with new regulations and policy.	O M	22 4
66. Need to develop inspection procedures and tools to ensure accurate application.	S	15, 16
67. Lack of detailed human factors information in MSM volume on investigations.	S	16
68. Lack of integration between CG offices, e.g., MVI, MVP, MMI and R&DC.	O	22

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APPENDIX C

Detailed Human Factors Technical Approaches

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APPENDIX C
DETAILED HUMAN FACTORS TECHNICAL APPROACHES

MANNING, QUALIFICATIONS AND LICENSING PROGRAM AREA

1. Job/Task Analysis of Shipboard Activities

Description of the Problem:

The job activities of ship personnel are presently defined by the type of ship, the trade pattern, position within the hierarchy (e.g., licensed/unlicensed) and broad organizational distinctions (e.g., deck, engine and steward department). There appears to be relatively little formalized information available, either in industry or government, that specifies the job and task content of shipboard personnel. This leads to difficulty in understanding the impact of automation on shipboard personnel structure, the development of valid licensing exams, and in creating a personnel subsystem in which certain fundamental skills such as emergency response are redundant. In order to establish an adequate technical basis for such activities, it is necessary to conduct a job/task analysis of ship personnel activities. Prior work in shipboard job and task analysis (Denny, 1987; National Research Council, 1990) either focused on shipboard organizational concerns such as participative management, and indicated that a more detailed approach should be undertaken. Such an approach is exemplified in the ship studies conducted in the 1970s by the Stanwick Corporation (1971).

Technical Approach:

Job task analysis (JTA) can be conducted at various levels of detail, depending on the exact purposes for which the information will be used (Harvey, 1991). Based on the problems that have been identified by the Coast Guard and industry, it appears that JTA data can be used to fulfill four purposes: (1) increase the validity of the licensing structure and examinations, (2) provide a basis for determining the impact of proposed manning reductions and job redesign, (3) facilitate the development of job function-based training, and (4) facilitate the design of automated equipment. The initial step in conducting JTA for these purposes is to verify the functions to be served by the JTA data, and to specify more fully the level of detail required. This should be accomplished by establishing a JTA working group comprising USCG HQ personnel, job/task analysts, and subject matter experts. This group will provide continuity and guidance throughout the performance of the task. The functional taxonomy developed by the National Research Council (1990) will provide a useful starting point for a detailed JTA; however, this taxonomy needs to be matched to the classes of personnel performing the functions, and more detailed data concerning the task elements of the job functions will be required.

Prior to describing a specific technical approach, it is important to define specifically what is meant by JTA. Job analysis, according to Harvey (1991) is a "collection of data describing the (a) observable job behaviors performed by worker including both what is accomplished, as well as what technologies are employed to accomplish the end results, and (b) verifiable characteristics of the job environment with which workers interact, including physical, mechanical, social and informational elements." Task analysis, according to Miller (1953) "consists of the enumeration of the discriminations, decisions and action responses which are necessary and sufficient to operate ... a man-machine combination." Over the years there has been some confusion about the relationships between job and task analysis. In essence, job analysis is concerned with functional level descriptions, i.e., groups of discrete tasks that are aggregated to form a job performed by a single incumbent. Task analysis, is focused more on individual human-machine or human-human interactions for purposes of interface design. The two types of analysis are concerned with inherently different levels of performance, both of which are important for purposes of licensing, manning, training and design. It is suggested that task analytic information, in terms of the specific human-machine and human resources interactions be conducted as an optional task following the development of job analysis information, since the level of detail required in a task analysis requires a much more intensive focus on information usage and cognition.

The approach to JTA for personnel activities will need to be a set of successively implemented tasks, each of which will build on the results of the previous task. The tasks should take place according to the following sequence: (1) Obtain and review industry-based JTA material; (2) Obtain and review training school material; (3) Define job classifications for further analysis; (4) Select or develop tools for JTA; (5) Apply JTA tools to selected job classifications; (6) Document results. This sequence of 6 tasks will involve increasingly detailed analyses of jobs that are selected to represent the range of activities conducted across a meaningful set of ship platforms.

The first two tasks are basically preliminary activities to an in-depth analysis of ship personnel jobs and tasks. It is likely that the overall job responsibilities of licensed and unlicensed personnel are described in procedure manuals developed by individual shipping companies. A review of this material will indicate the extent to which it meets the criteria defined above for JTA, i.e., observable aspects of the job, verifiable aspects of technologies and environment, and enumerations of the psychological processes and information utilized. These initial job function descriptions can serve as input to the next 3 tasks which will involve developing an extensive information base on ship personnel job classifications.

Task 3 will be to identify meaningful subsets of shipboard jobs for further analysis. That is, rather than analyzing every single position for a 21 person crew, it will be more useful to analyze classes of position, e.g., licensed deck officers, licensed engineers, unlicensed deck officers, unlicensed engineers, and radio/electronic officers. It will probably be necessary to include personnel involved in the

steward's department also, because of the importance of performing certain emergency functions. In addition to defining generic classes of shipboard jobs to be analyzed, this task will need to develop a taxonomy of ship platforms on which those jobs are performed, since the work of the human resources will vary quite dramatically from tanker to containership. This taxonomy will also influence the construction of function and task lists to be used in subsequent data collection.

Since there are multiple purposes to be served by the JTA data, the level of detail obtained in the analysis should be relatively fine. At this point a decision needs to be made as to whether to use specific task element inventories to cover all possible job activities for the range of positions and ship types defined in Task 3, or whether the use of an existing job analysis instrument, such as the Position Analysis Questionnaire or Job Element Inventory would be appropriate. It is likely that the custom-made task element inventory is the preferred option, because standard tools have been developed primarily for land-based jobs, and are highly generic. However, the application of such tools prior to developing a custom inventory would facilitate development of a more specific tool. Data from administration of the existing JTA tools should be used by job analysts, in conjunction with a small group of subject matter experts (SMEs) to develop a comprehensive task inventory for the range of jobs and ship platforms specified in Task 3. The task inventory should be validated by a separate group of subject matter experts representing the range of ship platforms and jobs contained in the inventory.

Task 5 will involve administering the comprehensive job/task inventory to a representative sample of job incumbents. This sample should be sufficiently large in so that stable parameter estimates can be obtained, e.g., at least 10 data points per cell. The purpose of this step is to obtain quantitative information concerning the frequency and criticality of each of the task elements for the classes of jobs being evaluated. For example, across the sample, the frequency and criticality of an item such as "perform crude oil washing of cargo tanks" will vary, principally in terms of ship type, but also within the human resources of a particular type of ship. The data resulting from administration of the task element inventory will provide the basis for developing detailed descriptions of particular job requirements, identifying areas where there is significant overlap in the jobs performed (offering the potential to either combine ratings or redesign jobs), and permit the development of more objective training programs and selection/examination criteria. The information obtained in the job inventory survey will be documented in Task 6.

As described above, an option should be considered for conducting more detailed task analysis of human-machine and human resources interactions for selected positions evaluated in the job analysis. Candidate positions for this more detailed analysis can be identified on the basis of job analytic information, such as percentage of time spent on particular tasks, frequency, criticality, etc.

Additionally, to the extent that certain key positions (e.g., licensed deck officers) will be interacting with electronic display systems, such an analysis would provide additional design-relevant information.

Another optional task that should be considered for this work is development of a procedure for incorporating background information in selection decisions. This would involve a retrospective study of company records to determine personal status, and using statistical techniques to establish the utility of background data such as driving record and criminal background.

Resources and Timetable for Accomplishment:

1.5 staff years for 24 months; total = 3 staff years.

Products of the Task:

The principal product of this task will be an objective description of the job functions and tasks performed by the human resources on a range of commercial ships of typical concern to the Coast Guard (tankers, cargo ships and passenger ships). These descriptions will provide detailed information on both the job functions required of different ships, and the functions of individual personnel manning those positions. As such, the data will address issues of manning requirements and licensing. Further, they will provide the basis for training program development and for evaluating the potential for automating various tasks that are currently performed by ship personnel.

2. Establish Equivalencies for Simulator and Operational Experience for Different Ship Platforms

Description of the Problem:

Current Coast Guard licensing regulations are based on the amount of time a mariner has spent in at-sea duty, and on the ability to pass written tests of knowledge. In an industry where it is likely that ship personnel will move from one type of ship to another, possibly involved in different routes and types of trade, the utility of simulator training increases greatly. By offering the ability to replicate the key performance features of particular ship types and situations, officers can gain experience in situationally specific aspects of shiphandling without necessarily having firsthand experience. The handling characteristics and fidelity of simulators such as CAORF can thus enhance, and perhaps substitute for sea time. Unlike the airline industry (Caro, 1988), however, the Coast Guard does not have well-specified equivalencies for substituting simulator training for sea time. The Code of Federal Regulations (46 CFR 10.304) states a general decision rule permitting combined training course and

simulator work to substitute for "a maximum of 25 percent of the required service for any licensing transaction." The Coast Guard specifies sea time substitution for training courses on a case-by-case basis. In view of the potential utility of simulators for complementing licensing exams by means of proficiency checks, and for providing experience in situations not previously experienced by trainees (and perhaps not likely to be experienced even over an extended period), it would be beneficial to have a better mapping of ship simulator experience to the actual requirements of sea duty.

<u>Technical Approach</u>:

The initial step in approaching this problem will be to review the current procedures used by the Coast Guard for approving training courses and crediting simulator time for sea time. Existing procedures appear to involve granting 1 to 1 credit for training hours and sea time, if a course is approved. Increments in that ratio can be made if various aspects of the training course are deemed "exceptional," such as the instructor, the simulator and other facilities. This approach adopts the "realism" philosophy of simulator effectiveness, and does not necessarily consider other aspects of the training situation, such as procedural fidelity, visual cue salience, etc. The review of current Coast Guard procedures for equating sea time and simulator training will be evaluated in terms of the sophistication of the training model underlying the process. This evaluation will show where there are weak links between sea time as specified by regulation, and the potential benefits of simulator training.

The little research that has been done in this area in the maritime environment has attempted to develop transfer functions that predict how much of a certain kind of experience (such as right of way situations) might be encountered in a sea tour, and to develop training course content on that basis (e.g., Meurn, 1989). Evaluations comparing the performance of simulator trained personnel, with those who have had actual sea experience, suggests that there is an increase in knowledge levels and performance proficiency obtained with simulator training in the absence of sea time (Kayten, et al., 1981; Aranow, 1978). While intriguing, these results must be viewed with caution because of the potential influence of practice effects with the simulator. However, they do suggest a strategy toward establishing better links between simulator training and sea time.

Since the airline industry has had long experience in using simulator training for everything up to and including initial pilot certification, the regulations and procedures used in the aviation area should be evaluated for the potential applicability of some of its procedures to maritime training. The results of this review will suggest further direction for work in the area of ship simulators. Likely directions include the following: establishing specific training objectives associated with simulator training courses; delineation of the assumptions underlying sea time requirements in terms of the range of experiences encountered and their frequency; evaluating the content of ship simulator training in terms of the assumptions underlying regulations; and, suggesting improvements in training course content to

better substitute for the regulatory requirements. Additionally, improved procedures for proficiency checks related to various license categories may be suggested by the results.

Resources and Timetable for Accomplishment:

.75 staff years for 9 months; total = .56 staff years.

Products:

The main product of this work will be an assessment of the state of the Coast Guard procedures for equating sea time and simulator experience in terms of the validity of the underlying assumptions in both regulations and training course content. Recommendations will be provided for improving both regulatory requirements, and training course content in order to provide more specific training objectives to be met by either sea time or simulator experience.

3. Develop KSA Profiles to Link Time in Grade License Requirements with Type of Experience

Description of the Problem:

Existing licensing regulations were implemented in 1989, and reduced the number of designations from 105 to 45. The system was implemented to eliminate trade and ship type distinctions. As a consequence, there are no license delineations based on the type or size of vessel (e.g, coastal tanker, VLCC or ULCC) or for tonnages above 1600 GT. As pointed out by the Coast Guard Tanker Safety Study Group (1989), "no longer is a master of a small coastal tanker of 4000 DWT qualified in a practical sense to command an LNG, LASH, large containership or ULCC." Because the qualifications for operating various types of ships under different trade routes are not reflected in the licensing structure, there is a loss of quality control over the composition of the ship human resources. While industry appears to self-regulate this issue, it would be desirable to have more formal information available to assist industry in ensuring a proper match between the experience of a particular officer, and potential assignments. Additionally, such information (e.g., a mapping of experience requirements for potential assignments to time in grade, with potential substitutions), would permit a better assessment of the manning structure of foreign flagged vessels.

Technical Approach:

The approach to this task will be a refinement and extension of the work performed under the Job Task Analysis, described above. The output of the JTA will be a set of generic job descriptions for certain classes of ship, to be defined in the course of the work. Establishing KSA profiles for specialized ship platforms will be a matter of refining the baseline JTA information to include the experience or knowledge required to work effectively on the ships of interest.

The initial step in this task will be to define areas where there may be potential problems, such as the types or nationality of ships operating with personnel who have inadequate experience or training. It is unrealistic to try to develop KSA profiles for every different type of ship platform; instead, this analysis should focus on those areas where the largest potential safety gain will occur. This can be accomplished by a review of casualty investigations, enforcement actions, and interviews with district personnel (such as the OCMI) who are likely to encounter these mismatches fairly often. Additionally, it would be useful to review the policies of shipping companies to determine the levels of training and experience they require of personnel in addition to the license. It is apparently common for a mariner who is qualified at a higher level to sail at a lower classification until he obtains the knowledge required to be proficient on a particular ship (e.g., an unlimited chief mate who only has bulk cargo experience sailing as 2nd mate on a crude oil tanker for two tours, and taking supplemental training before sailing as chief mate).

After the focus of the work has been narrowed to a manageable number of ships, a "KSA transfer matrix" should be developed. The purpose of the transfer matrix is to identify the potential transitions that can be made from one ship to another, and to facilitate the analysis of transferrable KSAs. A simple example of a matrix entry would involve a newly licensed third mate with limited sea experience taking a position on an LNG tanker. A more complicated example would be a newly licensed unlimited master with strictly bulk cargo experience transitioning to a crude oil tanker. The purpose of identifying these potential types of transition is to develop "case examples" of experience/training required by law, versus that which experts deem to be necessary for proficient performance.

A method similar to that employed with the JTA described above will be used for this work. Based on the ship types identified in the initial phase of the work and the contents of the KSA transfer matrix, an SME panel comprising licensed officers, training experts and USCG personnel (G-MVP, OCMI) should be assembled. The purpose of this panel is to refine the generic job position KSAs developed in the JTA described above, to include KSA requirements for specific ship types. Further, the JTA will facilitate developing KSA descriptions for the input side of the transfer matrix, i.e., the KSAs that serve as baseline (i.e., the training/experience required by law). The specific procedures to

be used for this work will involve adaptations of job/task analytic approaches that entail rating of the importance, criticality and frequency of various job functions (Fleishman and Quaintance, 1984). These ratings will be obtained from subject matter experts and human factors/training experts, to ensure that both operational and psychological perspectives are represented. The comparison of KSA profiles for the input and output sides of the transfer matrix will illustrate the areas where existing regulations may be inadequate in delineating the experience necessary to perform various shipboard jobs proficiently.

In addition to establishing training transfer functions, this task should evaluate the extent to which time in grade (now a principal licensing requirement) translates to breadth of experience. This is not a straightforward problem, since many years in a particular license grade can result in great breadth of experience, or be obtained on a single type of ship. The most feasible approach to this task would be to conduct a review of licensing documentation for a sample of mariners, with varying levels of experience. The review should be conducted on the basis of a protocol developed to reflect the breadth of skills described in the refined JTAs discussed above. Evaluation of the results with analysis of variance will indicate whether trends exist toward greater breadth of experience with longer service. If the data are amenable, it may be possible to develop a regression model to predict breadth of experience from years of service. However, such a tool must be applied with caution, since there will inevitably be individual variation.

<u>Resources and Timetable for Accomplishment</u>:

1.0 staff years for 12 months; total = 1.0 staff years.

<u>Products</u>:

The results of this work will be a "skills transfer matrix" that will illustrate the degree to which training and experience required by law readily transfer to specific shipboard applications. By indicating the extent to which statutory requirements and operational requirements of jobs are mismatched, specific "job transfer functions" consisting of training enhancements can be developed. Individual officers lacking certain experience would follow the prescribed training transfer function, and then be ensured of possessing the requisite KSAs for a particular type of ship. Additionally, guidance documents for evaluating the qualifications of foreign flagged crew aboard various types of vessels can be developed; this latter type of product will facilitate comparison of U.S. and foreign manning standards, and permit a more objective evaluation of the safety of foreign flagged vessels entering U.S. waters.

4. Develop a Tool to Assess Changes in Manning Structure on Ship Safety

Description of the Problem:

Economic and technological changes, combined with outdated regulatory policies illustrate the need to develop a technical basis for manning levels. Technological innovations have led to unattended engine rooms, and the future promises further advances in navigation equipment that include electronic chart displays and integrated bridge designs. Along with technological advances, economic pressures continue to increase. Much of the economic pressure stems from foreign flagged ships that use lower manning levels, and less expensive seamen. The combination of increased technological sophistication and economic pressures have led some to question the manning policies specified by Coast Guard regulations, and economic viability of U.S. flag ships. At the same time the need to maintain safety makes officials hesitant to lower manning levels, without firm evidence that such a reduction would not reduce current safety standards. Driven by the need to reconcile technological advances with economic pressures and ship safety, the marine industry needs a method to determine the effect of modifying the crew complement of ships. This solution provides a framework for evaluating models, and a procedure for selecting and developing appropriate manning models.

Technical Approach:

The solution approach to this problem depends on four elements. The first involves a detailed specification of the manning model. The second involves the collection and evaluation of data associated with the staffing needs of the ship. The third element relates to the development of a computer-based model that provides predictive estimates of the effect of manning on ship safety. The fourth element involves additional modeling efforts that elaborate on the initial model, rectifying the inadequacies of the initial model. Together, these four elements provide a technical basis for ship manning, addressing such issues as the ability of a different crew configurations to manage the ship within workhour limitations, to maintain the ship adequately, to respond to emergencies, and to adapt effectively to automation.

The first element in the development of a manning model involves producing detailed specifications. These specifications are crucial to the development of a useful manning model because they set data and software requirements. In addition, they also specify who will use the model and the types of questions that might be addressed. Interviews with the final users of the manning model at Coast Guard Headquarters will provide input into model specifications by determining the role of the proposed model in the regulatory process, and the detail , scope and accuracy of the model.

The second element involved in creating a manning model consists of collecting data that describes how operators currently perform the tasks. The actual data collected in this step depends on the model specifications, but it might include a detailed observation of the current operation, operators' subjective ratings about task frequency and duration, or a task analysis based on the design specifications of the ship. The observations may be quite informal, summarized in a qualitative description of the operator's behavior. On the other hand, they might be captured on video tape and subjected to a more quantitative analysis. In some cases asking operators to "think aloud" and analyzing the resulting verbal protocol would provide additional insight into the mental components of the operators' tasks. Whether the observations are summarized informally or subjected to a quantitative analysis depends upon the existing knowledge of the task and the number of tasks that the automation might replace or modify. In addition to observational analysis, using subjective ratings of operators provides simple method of determining the time associated with different tasks. Questions that require operators to specify the percentage of time spent on different tasks, or the relative frequency of tasks provide data have been successfully used to support an analysis of the effect of automation (McCallum, 1991). Since the data collection phase of model development involves substantial time and resources, it should be coordinated with other task analysis projects.

The third element in the development of a manning model involves creating and incorporating the data from a task analysis with the modeling tool identified in developing the model specifications. A number of different techniques are available to develop such a model. One technique uses a spreadsheet to calculate the overall impact of the automation by multiplying the frequency of task occurrence with the expected task time, with and without automation (McCallum, 1991). More sophisticated models might include information about the dependency between tasks, task priority and the consequences of error. These more sophisticated techniques illustrate how automation influences the overall efficiency of the operator, revealing the ability of the automation to overcome information processing bottlenecks and eliminate error prone tasks. Depending on the tool adopted and the scope and detail of the model, incorporating the data into a model requires relatively little time. However, after the data is incorporated into the model it must be validated, and this may require many hours of verifying the model output, comparisons to existing data, and even additional data collection to verify model predictions.

Since automation has the capability to fundamentally change the nature of operators' tasks, in ways that cannot be anticipated before its implementation, observing the operator interact with the actual automated system is a crucial step in the evaluation of the impact of automation. After the automation has been installed aboard a ship the second element development process might be used again. Here surveys, observations, and protocol analysis provide a detailed description of the effect of automation on the performance of the ship. In addition, this information provides a means of further validating the model. Since the model should accurately predict the effect of the automation, the post-installation

analysis should match the predictions of the model. Any mismatch between the model and reality provides an indication of how the model might be modified to better reflect the effect of automation in other circumstances.

After incorporating data into a modeling tool, and validating the resulting model, it can be used to identify aspects of the ship that are particularly important to ship safety. Through sensitivity analysis, the model can provide gross estimates that show which factors contribute most to ship safety. After identification of these factors, additional detail can be incorporated into the model to reflect the importance of these factors, economically increasing the accuracy of the estimated effect of different manning structures on ship safety. This process might lead to the development of a series of more detailed and focussed models. These models would address emergency response capabilities, maintenance requirements, and human adaptation to automation. If data for these models could be collected through existing projects, substantial resources could be saved; however, some models may require special efforts. For example, a model that examines maintenance activities would require a statistical analysis of the historical data on ship maintenance.

Products:

The products of this task include: 1) detailed specifications to guide manning model development, 2) a validated manning model, based on data collected through a comprehensive task analysis, 3) a sensitivity analysis of sample model output to discover needs for additional, more detailed manning models, 4) development of additional models to refine the predictions of changes on manning structures on ship safety. Together these four elements provide a predictive estimate of the effects of different manning structures on ship safety. The results of this task can be used by the Coast Guard to establish the methods it would recommend to industry for defining manning levels, and for evaluating the results of industry submission. As such, manning models developed in this effort would not be prescriptive, but instead describe and illustrate a set of methods for establishing manning levels across a variety of ships. The results of individual ship owner analyses would then be evaluated by the Coast Guard in light of the criteria for appropriate model application.

Resources and Timetable for Accomplishment:

1) Development of model specifications. 1 staff member for 3 months; total = 0.25 staff years.

2) Development and validation of manning model. .7 staff member 12 months; total = 0.7 staff years.

3) Sensitivity analysis and specification of more detailed models. .7 staff member 6 months; total = 0.35 staff years.

4) Develop additional models (2) to refine original. 1 staff member 9 months; total = 0.75 staff years.

Preceding resources allocation and timetable assume that other projects will provide the data for these models. Additionally, these estimates are contingent on the results of the model specifications developed in the first step.

5. Cognitive tradeoff analysis of automation impact.

Description of the Problem:

Increasing levels of automation on board ships have led to human resource reductions, and the alteration in how certain job functions are performed. In particular, automated systems offer the prospect of reducing physical workload and some of the sensing/control tasks previously performed by humans. They also place new demands on human cognitive processes, such as attention and memory. The basic question to be addressed in this work is the extent to which new automated systems that are being installed on ships, such as engine room alarm/monitoring and collision avoidance systems, reduce error prone repetitive tasks performed by humans, and the extent to which they place new and possibly greater demands on the limited capacity of human operators to process information.

Technical Approach:

The impact of automation on cognitive workload can be evaluated by developing a functional taxonomy of shipboard cognitive tasks in the engineering and deck departments to determine the loads and demands imposed on personnel by various levels of automation/technology (e.g., demands on short-term memory, attention, verbal abilities, etc.). This analysis provides a basis for evaluation of different configurations on personnel task performance. It will support the broader issue of developing manning models, and guidance for the implementation of automated systems. Previous task analytic work (e.g., National Research Council, 1991; Denny, 1987) was not oriented toward cognitive functions, but instead focused on generic shipboard activities. Thus, an extension of previous functional analysis into the cognitive domain is required.

A cognitive tradeoff analysis entails a comparison of the cognitive processes and operations demanded by the tasks performed by shipboard personnel under conditions of manual and automated operations. While this distinction is probably more simplistic than will actually be encountered, it will help to describe the approach to be taken to this work. By systematically documenting the alteration in shipboard task performance resulting from the introduction of various automated systems, the Coast Guard will have a more rational basis for determining manning levels, and industry will be able to accurately forecast the impacts of automation on manning scales and the economics of their operations.

The approach to this task should involve the use of a relatively new human factors technology known as cognitive function analysis. The initial step of the work will involve adapting existing shipboard function taxonomies to include the cognitive requirements of the work. Cognitive taxonomies used in

accident databases should be reviewed and adapted for this purpose. When these functions are defined, they can be compared as to their relative level of demand when performed in a primarily manual fashion, and with the assistance of automation. The extent to which different cognitive loads are shown to exist between manual and automated conditions will help to understand how tasks change, and how jobs may be re-configured to make the best use of human resources.

A typical functional taxonomy would involve a functional breakdown of activities in the bridge, deck and engineering areas, and would include such activities as navigation, lookout, ship control, cargo activities, communications and machinery activities (e.g., alarm surveillance, diagnosis, etc.). Since the purpose of the task is to evaluate the cognitive tradeoffs involved in automation, the most appropriate level of analysis would be at the function and task level. Functions are aggregated sets of tasks; tasks are more discrete components of functions; that is, the navigation function may involve a number of individual tasks, such as position fixing, course plotting, helm maneuvers, etc., and are performed by one or more individuals.

Once the level of analysis and appropriate functional taxonomies and automated systems have been identified, a matrix will be developed that will allow comparison of the cognitive requirements of the functions and tasks identified. The cognitive processes and abilities will be extracted from the many previous analyses performed in other industries (see Fleischman and Quaintance, 1984); additionally, SMEs in the shipboard functions and tasks identified will be interviewed to validate the application of previous work. The cognitive function/shipboard function/level of automation matrix will then be evaluated by a panel of subject matter experts on shipboard operations. They will be asked to rate the relative importance of each cognitive process and/or activity in the automated and non-automated functions, and the relative workload involved.

The resulting data will allow the development of "cognitive profiles" of particular shipboard functions; these profiles will depict the relative demands imposed on the cognitive abilities of the human resources, and how these demands have changed with the introduction of automation.

Resources and Timetable for Accomplishment:

.6 staff years for 9 months; total = .45 staff years.

Products of Task:

The primary product of this work will be a technical report describing the impact of automated systems on the cognitive functions performed by ship personnel. The analysis will be directed at specific equipment and systems, such as Automated Radar Plotting Aids, centralized alarm panels, and

integrated bridge systems (and components). Comparisons with manual or conventional methods will indicate the extent to which new cognitive demands are placed on personnel, such as short-term memory, multi-target attention and spatial processing. An evaluation of these processes on overall job structure in terms of workload and potential for error will be provided. The report will translate these effects into general human-machine interface design and training guidelines that can be used by the USCG to develop NVICs and policy guidance letters. The approach used in this work can be employed by the Coast Guard as a general method for evaluating the potential effects of automation at the cognitive level.

6. Evaluation of Training in Support of New Technologies

Description of the Problem:

The trend toward increasing use of electronics and computers on board ships requires that ship personnel possess the requisite knowledge, skills and abilities (KSAs) to operate and maintain automated systems. The primary means of achieving these KSAs is through training, either vendor supplied, on-the-job, or in schools. There is concern over the training issue in several areas: (1) whether in a retro-fit situation, vendor supplied training adequately addresses the operational requirements of the ship (e.g., is training supplied to the right people?), (2) the extent to which training imparts accurate "mental models" of how the technology works, and (3) how well existing training schools are preparing prospective ship personnel to work with automated systems. The ship of the future will be much more oriented toward "information systems and management" and training at all levels needs to accommodate this change.

By increasing the level of automation on board ships, personnel have reported several problems and issues associated with the new technology. In general, the Coast Guard and the industry recognize the need for more in-depth training related to operating, interpreting, and communicating information obtained from automated systems. Based on the human factors issues summarized in the first section of this solution proposal, training for automated systems should provide the following:

- a clear linkage between actions and processes used to perform in a training simulator and actions and processes required to operate and interpret data from automated systems on board ships.

- clear guidance and procedures for using autopilots and procedures for communicating this information.

- a more in-depth understanding of the capabilities of ARPA and ECDIS and knowledge of procedures for using all of its functions more effectively.

The questions addressed in this activity are: (1) what type of training is needed and by which personnel to meet immediate operations needs; and (2) what type of training is needed in the future to ensure correct implementation of new technologies?

Technical Approach:

The work proposed to address training needs as a result of new technologies focuses on both immediate training needs and future training needs. Procedures for identifying and developing training programs to meet immediate needs is described first, followed by a description of procedures for determining and responding to future training needs.

Immediate Training Needs Assessment and Development. Procedures for determining the current training needs for using automated equipment coincide with conducting the Job/Task analysis. Training needs can be assessed at the same time job and task information is collected. Typically, job and task information is collected by observing ship personnel as they perform their duties and by interviewing ship personnel to identify the critical tasks.

During the job/task analysis interviews, the Critical Incident Technique, (Flanagan, 1954) can be used to obtain information about current problems associated with the automated equipment (e.g. ARPA and ECDIS). This would involve interviewing personnel who operate the equipment or who rely on information from the equipment to make decisions. During these interviews, ship personnel would be asked to describe specific examples of incidents involving the automated equipment. Based on examples provided by personnel serving on a variety of ships, it is possible to identify immediate training needs that involve operating automated equipment. This work can also provide input to the user interface evaluation of ARPA and ECDIS, as described below.

Analysis of the critical examples are used to identify areas in which additional training is needed. These additional training needs can be compared to training that is currently available for personnel. This will be accomplished by observing in-house and on-ship training provided by vendors, and a critical review of training documentation. Specific attention will be devoted to those areas identified as critical performance factors by the personnel interviewed. Based on this comparison, recommendations for modifying the current training programs or for implementing new programs can be made. It is important to note that results from the critical incident interviews can also be used to identify personnel who require additional training.

Future Training Needs. To ensure that training needs are met now and in the future, we propose linking results from the Job/Task analysis with current training curriculum. Procedures for determining future training needs are to identify the critical components of the major job classifications (e.g., licensed deck officers, licensed engineers, unlicensed deck officers, radio/electronic officers). This task involves matching the current training programs for different job classifications with current job requirements. If the current training program does not provide adequate training to ensure that ship personnel can adequately perform their jobs, then the training curriculum and official training requirements should be modified. These modifications may have implications for licensing requirements and examinations also.

Also, to ensure that training requirements (and licensing requirements) match job requirements, it will be important to consider new technologies proposed for the Coast Guard and the commercial industry. Any new equipment that is currently under development or currently being implemented should be included in both the job/task analysis and in the evaluation of training requirements.

Resources and Timetable for Accomplishment:

.5 staff years for 6 months; total = .25 staff years.

Products of the Task:

Results from an analysis of the immediate training needs related to automated equipment will yield the following products:

- Assessment of the match between current training on automated systems and training needs. If differences exist, recommendations will be provided for modifying the current training program(s).

- Identification of which personnel require training on automated systems. It is expected that more personnel actually require training on these systems than receive it.

Results from analysis of job/task analysis results will be used to provide a broader review of training needs. This assessment will focus on all types of training (not just limited to training on automated systems), and will address future training needs that may result from the implementation of new technologies.

7. Workload/Link Analysis of Bridge Operations

Description of the Problem:

The complexity of bridge operations on large commercial ships can range from 4 to 5 persons, to 2 persons in U.S. flagged ships. These numbers reflect the requirements of transiting pilotage waters versus open sea conditions. With advances in automation, there are new possibilities to enhance the perceptual and control capabilities of bridge personnel, and a corresponding opportunity to reduce the numbers of personnel required for bridge watches in various conditions. The International Maritime Organization has established guidelines for conducting sea-trials of one-man bridge operations, and commercial manufacturers of navigation electronics offer their products as "meeting IMO standards" for one-man bridge operation. While the potential exists to complement human capabilities on bridge watch-standing, there is very little objective information concerning officer cognitive workload under the range of conditions that would be encountered in a typical voyage (e.g., piloted waters, unpiloted landfall conditions, unpiloted traffic situations, night operation, etc.). The existing experimental work evaluating one-man bridge concepts (Schuffel et al., 1989) has not provided detailed reports of the level of traffic used, nor introduced emergency conditions. Thus, in order to better understand the conditions in which reduced bridge manning may be appropriate, and how it should be supported by automation, more detailed information on bridge workload is required.

Technical Approach:

The approach to this work will involve two related activities: (1) workload quantification and (2) communication link definition. The two are related because if a communication link exists between two ship personnel and it is exercised, then workload increases. The principal objective of the technical approach is to use workload and link data to determine the extent to which there is potential for automation to either increase or decrease workload, and thereby alter the human resource requirements on the bridge.

Quantification of the workload of the members of the bridge team depends initially on having a classification scheme of operational conditions and human resource composition. For the purposes of this work, a relatively simple scheme is required, such as navigating in piloted waters, open sea, and unfavorable weather conditions. The purpose of this scheme is to identify a set of general scenarios in which the navigational or environmental conditions lead to substantially different ways of operating (e.g., more frequent maneuvering during pilotage transit, responding to unanticipated maneuver requirements during heavy weather, and monitoring without much overt intervention during open sea transit). The workload scenarios should be established on the basis of several sources, including

federal regulations, shipping company procedure manuals, simulator scenarios that have been developed for research and training purposes, and subject matter expert input.

The second step in quantifying bridge team workload under varying scenarios is to construct a task list of each team member for the scenarios under consideration. This task list should be based on a functional analysis of the general duties performed, e.g., navigation, watchkeeping, communication, etc. The task list will provide a more detailed description of the elements of each bridge team member function. Comparison of these task lists (as well as simply number of bridge team members) will provide a rudimentary indication of workload. In a sense, this step serves to validate the scenarios selected, since the task lists for more intensive scenarios should be longer and/or more complex in terms of human performance. Development of the task list should be accomplished by obtaining input from a panel of subject matter experts (i.e., multiple captains, third mates, helmsmen, pilots, and lookouts). The task list should be validated with observations of operational activity, and by use of a holdout sample approach, i.e., construct an interim task list on the basis of an initial sample, and validate the list with a subsequent sample..

The task list data should then be plotted against a voyage phase/personnel timeline. This timeline would take the form of an analysis presented by Stoop (1990), in which various ship system functions, instruments, voyage phases and human factors variables were plotted according to their duration per voyage phase. This type of representation will allow a direct comparison of bridge team activities according to the specific tasks performed, by whom, for how long, and how often, for each of the workload scenarios. This type of task analytic representation is a relatively objective way of understanding the task factors contributing to bridge team workload under different conditions.

A complementary aspect of workload quantification will be to evaluate the communication links between bridge team members, and with external communicators, such as VTS and other ships. Since the goal of this work is to understand the relative workload levels across scenarios and personnel, the most efficient way to approach this task would be to develop a form illustrating potential communication links between various bridge team members under different team compositions and workload scenarios, and to have members of the panel of experts rate the strength of communication links (e.g., no communication, infrequent, constant). An appropriate scale can be developed on the basis of information available from training simulator studies. In addition to rating the strength of communication links, it is important to know the content of communication, since errors are introduced when critical data is not correctly transmitted. The resulting data will show the complexity and strength of communication links between bridge personnel and other sources.

Data from the task list/timeline analysis and the link analysis can be used to determine the overall workload levels for the various personnel who compose the bridge team under different circumstances.

The results may show, for example, that a third mate is has a relatively constant workload across different scenarios, whereas the helmsman, pilot and captain show peak workloads that are scenario dependent, and that are heavily influenced by a small number of tasks, such as forecasting maneuvers. The task timeline data and communication link data can both be represented as Operational Sequence Diagrams (OSDs). These diagrams portray the sequential operation of functions in terms of the human-machine information transfer, the human-human communications, and the resulting equipment responses.

Resources and Timetable for Accomplishment:

1.25 staff years for 12 months; total = 1.25 staff years.

Products:

The main product of this task will be a description of bridge operations on a generic ship that provides quantitative data on the workload and communication links for the various members of the bridge team under different scenarios. The quantitative information will be presented in terms of numbers and types of tasks, frequency, duration, and complexity. A byproduct of this work will be data concerning the instruments and data used to accomplish the tasks, thus providing a basis for developing automated systems such as piloting guides. Additionally, the data will provide a more objective basis for evaluating the performance of one-man bridge concepts, by suggesting ways in which rapid workload transitions can be simulated. This latter information can be used to develop guidance for bridge team structure, and reliance on automation, under various navigational conditions.

8. Workload Evaluation of Port Call Requirements

Description of the Problem:

Activities involved with port calls require special attention concerning the workload of ships' personnel. From the time the ship enters piloted waters until it is secured at the dock, the human resources must attend to a wide range of tasks not included in routine sailing. During this time the ship must not only navigate more precisely, but it must also prepare and deploy lines for docking, and coordinate with VTS, a pilot, tugs and shore side personnel. These activities impose a variety of cognitive and physical demands on the human resources of the ship. The match between these demands and the technological and personnel resources influence the safety of the ship. Examining the cognitive and physical workload associated with port calls reveals the demands imposed on the human resources. This becomes particularly important as technology proliferates, lowering physical workload but possibly increasing cognitive workload.

Technical Approach:

The technical approach to this problem involves three components: 1) a description of the physical demands, 2) a description of the cognitive demands, and 3) a description of the communication links. Each of these aspects of port calls plays an integral role in the ability of the human resources to maneuver and secure the ship safely: the physical demands because of the deck operations involving coordination of lines and preparation of cargo operations, the cognitive demands because of the precise timing and coordination of multiple events, and communication because of the number of personnel working to maneuver the ship.

The physical workload analysis associated with port calls focuses primarily on the deck personnel who are responsible for deploying the lines during docking and retrieving the lines during undocking, as well as preparation for cargo handling. A detailed description of the physical workload associated with port calls would include the manual actions (lifting, transporting, adjusting) along with the physical force, time, and coordination with other personnel required to carry out the actions. Cataloging the demands associated with all the physical activity associated with port calls would provide a basis for estimating the workload of individual personnel, as well as a method for assessing how that workload might change with various design modifications. For example, a catalog of the exact tasks involved in line deployment and adjustment would provide a basis for estimating the workload savings associated with implementing automatic tension control mechanisms or light weight lines. Additionally, a catalog of all the physical requirements would reveal how proposed manning reductions, based on design changes (introduction of lightweight lines) of one aspect of the docking operation, might affect other aspects of the docking operation (preparation for cargo loading).

In addition to the physical demands associated with port calls, the cognitive demands require a thorough description so that new technology can be developed for ships in the most effective manner. An analysis of the cognitive demands associated with port calls might begin with a timeline that includes the moment to moment activities of not only the bridge personnel, but also the deck crew, shoreside personnel and the tugs. This timeline approach would include information about the time duration of tasks, as well as the memory, computation, coordination and data sources associated with each task. In addition, the interrelationships between the tasks shown in the timeline could provide insight into the constraints that exist in the process, illustrating the bottlenecks that technological innovations must overcome to be effective. Likewise, the catalog of data requirements associated with the tasks on the timeline would provide a means of generating new displays that give operators the information they need in the most appropriate form.

Related to the issue of providing the operators with the information they need to carry our their tasks would be an analysis of the communications involved in port calls. Because port calls require communication between a wide variety of people (including tugs, pilot, helmsman, mate, captain, deck crew, shoreside personnel, and VTS operators) communication plays a major role not only in the delivery of information, but also in contributing to the workload of all involved in port operations. A thorough analysis of communication would reveal any inefficiencies that might lead to poor transmission of information or unnecessarily high levels of workload. One possible means of analyzing communications would be through link analysis. This technique could be enhanced to include not just the frequency of transmission, but other characteristics of the messages, such as purpose, channel, importance, urgency, and possible redundancy. This analysis would reveal the degree of coupling between participants together with the importance of this coupling. For example, safety of the ship during docking depends on the close coupling between the pilot and the tugs; however if the analysis reveals a relatively weak coupling then design modifications might produce a closer coupling. This analysis might become increasingly important as ships become more highly automated and new methods of communication replace the traditional, well known, channels.

Resources and Timetable for Accomplishment:

.6 staff years for 6 months; total = .3 staff years.

Products:

The products of this task consist of three items; a detailed description of the physical demands imposed on the deck personnel, a detailed description of the mental demands on bridge and deck personnel, and a detailed description of the communication channels. These descriptions provide the basis for a quantitative analysis of the task demands with respect to the technological and personnel

resources available during port calls. This comparison will provide a firm basis for evaluating how best to design and implement technology and automation to support the ship's personnel during port calls. Comparing the task demands to the personnel and technological resources illustrates how technological innovations must integrate with the rest of the ship, as well as the shoreside personnel, to effectively support the entire port call scenario, as opposed to isolated aspects of it.

9. Workload/Link Analysis of Cargo Transfer Operations

Description of the Problem:

Cargo operations involve both shipboard and shoreside personnel in the loading or offloading of ship contents. In the case of bulk cargo ships, most of the work is done by shoreside personnel and equipment, although the chief mate ensures the quality of the operation. For liquid cargo, there is extensive involvement of shipboard personnel in starting pumps, monitoring tank levels and fill rates, communicating with shoreside personnel and checking for leakage. There is potential for human error in both bulk and liquid cargo operations; improperly loaded bulk cargo may shift and lead to critical imbalances; errors in transferring liquid cargo can lead to spills and potential explosions and environmental damage. To facilitate the development of automated cargo transfer systems, and to develop training and communication protocols that will reduce the potential for human error, quantitative information on the workload and operational sequence of cargo transfer activities is required.

Technical Approach:

An approach similar to that used to analyze the bridge team workload can be applied to the evaluation of cargo transfer operations. As with the bridge team workload analysis, the evaluation of cargo transfer should focus on the development of task lists and timelines for workload quantification, and defining communication links.

In distinction to bridge team operations, which can take place under various navigational scenarios, cargo operations will be routine; that is, the structure of the team performing the operations, and the sequence will consist of a set of core activities that always occur. There will be variations in the exact details of these operations based on the port and cargo being loaded or offloaded, but the principal operations will be routine. Thus, the focus of the workload analysis for this task will be primarily in comparing the tasks of individuals engaged in the transfer operations, and the operations required by different types of loads.

To develop the task lists, a functional model of cargo transfer for bulk and liquid cargos should be developed. The number of functional models should be determined by the extent to which distinct differences exist between cargo operations for different types of loads, e.g., crude oil, liquid natural gas, bulk forest products, bulk chemicals, liquid chemicals, and containerized cargo. The functional models will be developed on the basis of a panel of subject matter experts composed of chief mates (the usual cargo officer) from ships carrying the range of products of interest and appropriate shoreside personnel, such as port cargo masters or crane operators. The expert input will be complemented by field observations and interviews. The functional model will portray the sequential flow of operations at a relatively high level, e.g., "calculate stability," or "activate pumps." The purpose of the functional analyses is to provide models for developing task lists.

On the basis of the functional models, the panel of experts will provide more detailed input regarding how each functional aspect of cargo transfer is carried out. This will include specifying the personnel involved, the tasks they perform to accomplish or facilitate the cargo transfer functions, how the tasks are done (i.e., the specific information accessed and acted upon, and by what means - equipment, manually, or mentally), and the duration and frequency of the tasks. The task level information will be represented in a graphical form illustrating the relationship between personnel, cargo transfer function, specific task activities, and time as described in the bridge team workload analysis above.

In addition to the individual personnel task lists, communication links between members of the cargo team should be identified and characterized. As in the description of the bridge team communication link analysis, a form will be developed for rating the strength of communication links, as well as defining the content. To the extent possible, information will be obtained regarding the periodicity of communications in cargo transfer, i.e., at what intervals communication takes place between ship and shore. It has been reported anecdotally that overly long communication intervals between the pump control room and shoreside cargo control can lead to overfilling and spills.

The data obtained from the functional models, task lists, timelines and link analyses will be represented as operational sequence diagrams. Quantification of workload for individual personnel involved in cargo transfer will be accomplished by comparison of the task lists, timelines and communication links. These complementary dimensions of workload will indicate the extent to which particular personnel, or multi-person operations place potentially excessive demands on the operators.

<u>**Resources and Timetable for Accomplishment**</u>:

.75 staff years for 6 months; total = .375 staff years.

Products:

The results of this task will be a quantitative description of the workload of ship and shorebased personnel involved in cargo transfer activities. The data will permit the comparison of operational complexity across different types of cargo operations, and thereby be useful for training analysis and design. Additionally, the workload data will permit an assessment of existing or potential overloads (in terms of peak or longer duration periods) for individual personnel involved in cargo transfer, and an evaluation of functions and tasks in terms of human error potential. The analysis will provide the basis for development of company policies on shoreside support for cargo operations, guidance for team structure and job redesign (e.g., checklists and standardized communication protocols), and automation support.

10. Develop a Series of NVICs to Address a Wider Range of Human Factors Issues

Description of the Problem:

Human factors needs to be considered in the design of ship systems. The USCG could provide such guidance via NVICs. Navigation and Inspection Circular 89-04, Introduction to Human Factors Engineering, provides a reasonable tutorial on human factors in the first several pages. However, the design approach discussed is typically not the way that user interfaces are developed; this step often proceeds somewhat independently from hull design, and in the case of retrofitted electronics, has no interaction with the overall ship design and construction process. Further, experience has shown that user interface development tends to be largely driven by tradition and the current capabilities of hardware/software. With these realities in mind, it would be worthwhile to develop a more comprehensive and realistic approach to the design and implementation of automated systems for marine applications, which would influence both new design and retrofits. Additionally, NVIC 89-04 does not present new information; instead it reviews a single component of ASTM F 1166-88, concerning labeling; this is insufficient guidance for designers, and provides little utility to inspection personnel. Thus, a more comprehensive NVIC or series of NVICs addressing human factors would include a realistic design approach, and include more up to date information concerning user interface concepts, for both design and evaluation purposes. The end result would be the equivalent of a design engineer's handbook.

Technical Approach:

The main element of rewriting NVIC 89-04 will be to assemble and synthesize a large body of relevant human factors information that has not been previously incorporated into design standards.

The existing human factors design guide for marine systems, published by the American Society for Testing and Materials (ASTM F 1166) is essentially a replication of various military standards, which are quite detailed in description, but not illustrated with examples. Further, little information is provided about how to introduce human factors in the design process, or the use of various human factors methods.

An approach that presents an alternative to a highly detailed list of design features which are poorly linked to applications, is to present this type of data in a broader context, related both to design and regulatory processes. This can be accomplished by focusing on three areas where human factors can have a large impact: the initial design process, the design characteristics of the product or system, and in testing and evaluation. The first area will be of more interest to private companies and engineering firms; the second area would be of equal interest to engineering personnel and USCG personnel, while the third area would be the province of the USCG to certify equipment for acceptance. This latter activity may be performed by a third party lab, but criteria for testing need to be established.

Presenting human factors as related to initial design will be important for manufacturers in achieving human-system integration. Essentially, this is a process in which particular "mission requirements" are delineated, and the human factors aspects of a system are specified. This can be achieved through function and task analysis, which are the primary tools of human factors designers. A large body of writing has accrued on these topics, and the section on system design processes will condense this information into a series of descriptions at the tool level, such that readers will be able to directly apply a particular technique. Standard references (e.g., Miller, 1953; Laughery and Laughery, 1987; Stammers et al., 1990) concerning this information will be consulted and condensed. Where feasible, forms, checklists or questionnaires will be provided. An important element of this part of the NVIC rewrite will be to illustrate the application of the techniques with simple examples from the maritime environment.

Design characteristics of products or systems are typically what human factors specialists are most concerned with, and usually are the basis for design guidelines or standards. However, there has been a tendency to present information concerning such things as workstation design in isolation of the context in which the workstation will be used. As a consequence, a design guideline indicating that a cathode ray tube display should be placed so as to yield a viewing angle of 15 degrees off horizontal, may be inappropriate for ship bridge where there is often a large degree of backlighting. The purpose of the NVIC section on design characteristics is to more effectively link (and to modernize) the available material on hardware and software design. This includes not only traditional "knobs and dials" human factors, but also the variety of techniques that have been developed in the past decade for presenting and manipulating data on CRTs. A diversity of sources will be used to assemble this information, including a recently developed Department of Defense standard on human-computer

interfaces, published guidelines such as Williges and Williges (1984), and more recent descriptions of capabilities such as hypercard. The advantages and disadvantages of various display and control techniques for maritime applications will be discussed.

Test and evaluation is the final phase of a design process, and is meant to ensure that the system or product meets the specified requirements. In terms of human factors, test and evaluation can take place at one of three levels: (1) tabletop review of the product or system by independent human factors engineers, (2) self-report of users or operators of prototype equipment, and (3) actual human performance tests under controlled conditions with prototype equipment. Usually some combination of these three approaches is used. The NVIC rewrite will draw on the extensive test and evaluation literature (e.g., Meister, 1985; Wilson and Corlett, 1990) to describe approaches and tools that would be the most useful in various maritime applications. For example, in determining whether a new life jacket design should be certified for placement in passenger cruise ships, a set of self-report instructions for user evaluation could be developed on the basis of the performance requirements specified during design. More detailed testing under simulated emergency conditions could also be guided by test and evaluation methods discussed in the rewritten NVIC.

An additional function that should be served by a human factors NVIC is to provide basic information on human capabilities. While the nominal purpose of a standard is to embed human capabilities within design guidelines, there are too many potential design situations to expect that a set of static guidelines will always be applicable. Further, the philosophy of embedding human factors information in a guideline or standard assumes that the reader can induce general human performance principles from numerous specific examples. Since the NVIC will probably be used by many non-specialists, it will be important to articulate a set of general human performance principles on which the guidelines are based. Thus, for each guideline in the section concerned with design characteristics, a general principle will be stated. It is likely that there will be relatively few general performance principles that drive a substantial number of guidelines. Standard texts on human factors psychology and engineering will serve as the source for the development of design driving principles (e.g., Kantowitz and Sorkin, 1983; Wickens, 1984; Boff et al., 1986).

Resources and Timetable for Accomplishment:

1.25 staff years for 12 months; total = 1.25 staff years.

Products:

The primary product of this task will be a human factors NVIC that will be usable by a much wider range of people than is currently the case. First, by expanding topical coverage to a wider area than

labeling, many more marine systems can benefit from the guidelines. Further, by presenting the guidelines within the context of a design cycle, with associated design-aiding tools, the reader can be a more active participant in the use of the material. By linking design characteristics to human performance capabilities, a rationale can be provided for regulatory requirements. The test and evaluation section can be used as the basis for developing better inspection procedures, and for providing testing labs with more explicit acceptance criteria.

11. Adapt existing guidelines for alarm displays to the maritime environment

Description of the Problem:

Alarm systems in the marine environment have been developed with little consideration of how they might best communicate crucial information to ship personnel. While the IMO resolution A.686(17) provides guidance concerning what systems should have alarms, as well as some general guidance concerning alarm location and type, this document does not provide sufficient guidance to ensure that the alarms provide the ship's human resources with an integrated understanding of the situation. With the advent of unmanned engine rooms and advanced navigation technology, the number of alarms located on the ship's bridge will increase dramatically. In addition to the increased number of alarms, some alarms frequently activate in the absence of a problem leading operators to ignore or disable the alarms. These problems suggest that additional guidelines need to be developed so that alarms not only alert the ship's human resources, but also guide the human resources to mitigate a possible emergency. The need to incorporate cognitive aspects of alarm design, so that alarms present operators with a more coherent picture of the state of the ship, suggests that existing guidelines from other industries may be fruitfully adopted to the maritime industry.

Technical Approach:

Research on alarm functions in the nuclear and process control domains has developed a strong theoretical basis for alarm design. Adapting parts of this research would aid the development of design guidelines for the marine industry. This task will involve developing a generic model for alarm functioning in shipboard applications, and will evaluate the applicability of several specific design approaches. The principal objective of this task is to develop potential approaches to the display of alarm information that will be commensurate with personnel working with a more extensive array of automation.

While the IMO code on alarms and indicators (Resolution A.686(17), 1991) presents a number of guidelines to aid in the development of alarm systems for the marine industry, they are presented in a very specific format, with little rationale for the design recommendations. This provides little utility for alarm designers who are not developing applications that are similar to the guidelines. The initial step in this work will be to adapt an existing general framework for alarm functioning to the marine environment. Rankin, et al., (1983) present both a theoretical framework and concrete guidelines for alarm design for nuclear power plant control rooms. Specifically, they describe four functional criteria of alarms: alert, inform, guide, and confirm. For each of these functional criteria they illustrate how alarm effectiveness depends on specific design features, such as the sensory modality of the alerting signal, the visual presentation of trend quantities versus discrete digital values, etc. Their guidelines were based on a normative model of system troubleshooting in a nuclear power plant. In order to develop better alarm guidelines for the maritime environment, a similar model will be developed for marine applications. This will be accomplished by reviewing training material for engineering personnel, and the design characteristics of power plants and electronics. Additionally, structured walkthroughs of various troubleshooting scenarios will be conducted with engineering personnel. On the basis of these data, a normative model for power plant and electronics troubleshooting will be developed. In the same process, information will be gathered concerning problem areas such as false alarms or "alarm avalanche," i.e., a phenomenon of multiple alarms confusing the engineer as to the primary cause.

The normative framework for ship power plant and electronic troubleshooting will be used as the basis for evaluation of several specific approaches to alarm design that may be more useful than conventional annunciator panels, or the soft display emulation of such panels. For example, an operator's tendency to disregard alarms systems with a high rate of false alarms represents a specific problem. In this circumstance, operators learn to ignore or disable alarms, failing to attend to them when a problem actually occurs. The scientific literature in the areas of supervisory control (Sheridan, 1987) and signal detection theory provides a potential human factors design solution to this problem, as discussed by Sorkin and Woods (1985). These authors describe the situation where an operator works in parallel with an automated monitor or alarm that is prone to high rates of false alarms as an alerted monitor system (e.g., the bridge fire alarm panel). Their research, together with that of Sorkin, Kantowitz, and Kantowitz (1988), provides the theoretical and empirical basis for alarm design guidance that could be used in the marine domain. In particular, Sorkin, Kantowitz, and Kantowitz (1988) illustrated how Likelihood Alarm Displays increase the effectiveness of the operator's response to alarms prone to high rates of false alarms. These displays present probabalistic information as to the likelihood that an alarm is real; this approach, together with additional displayed information such as engine temperatures or other sensor information, could be useful in the development of less ambiguous alarms that are remote from the location they are sensing.

In addition to the guidance provided by the research on the alerted monitor concept, research concerning the development of alarm displays for nuclear power plants provides a theoretical basis for alarm systems in ships. In particular, the Integral Safety Parameter Display System (ISPDS), developed to aid operators in monitoring safety critical aspects of nuclear power plants, might be incorporated into alarm systems of ships. The ISPDS presents eight safety critical data points in a polygon that remains symmetric until one or more of the parameters deviate from its expected range. As the parameters deviate the polygon distorts, it presents operators with a striking visual indication of abnormal situations. The potential application of this technology to shipboard alarms will also be evaluated.

In addition to the ISPDS, the work of Beltrachi (1987) and Rasmussen and Vicente (1988) suggest methods to combine a large array of information in a way that supports an operator's ability to recognize emergency situations, and to mitigate their effects. Beltrachi's intelligent alarm display concept integrates the variables associated with the heat engine cycle of a nuclear power plant and presents the operator with a coherent understanding of the system. This understanding not only supports a more reliable recognition of abnormal situations, but it also supports more accurate identification of the specific type of fault. The extent to which such a concept is applicable to presenting alarm information on diesel and steam power plants on ships will be investigated.

Based on the evaluation of the alarm display concepts described above, specific recommendations will be made for the structure of alarm systems in shipboard applications. Depending on the findings, this may involve a single concept for all alarms, or multiple concepts and guidelines for different functional areas and systems.

<u>Resources and Timetable for Accomplishment</u>:

.75 staff years for 6 months; total = .375 staff years.

<u>Products</u>:

The results of this task will provide a human factors technical basis for the design of integrated alarm display systems in shipboard applications. A normative model of how shipboard personnel use alarm information will be developed; this will allow an evaluation of modern alarm display concepts, and facilitate the placement of existing guidelines (such as those of IMO) within a human factors context concerning how people use the information that alerts them to malfunctions. Recommendations concerning specific alarm display concepts can be incorporated into NVICs and other guidance documents.

12. Define Equipment and System Information Requirements of Ship Personnel for Various Routine, Abnormal and Emergency Situations

Description of the Problem:

The distribution of information from shipboard equipment is an important consideration in operations. It is usually the case that data from equipment is presented in some form close to the location of that equipment, and not remotely represented. For example, cargo tank levels are shown in the control room of a tanker, but not in the bridge or engine room. However, certain operational procedures that involve the interaction of multiple departments may be facilitated by having data from equipment presented in more than one place. An example would be taking a cargo pump offline as certain tanks are filled; in some ship configurations this would involve verbal communication between the engine room (source of power for the pumps) and the control room (location of the data); accurate communication of such information is important in order to prevent overfills or pump burnouts. With the development of automated systems for many aspects of ship operation, there is the prospect of presenting task-relevant data at multiple workstations. The quick availability of information at multiple workstations will be increasingly important as crew sizes are reduced. To effectively pursue this design approach, it is important to have an understanding of the information requirements of shipboard personnel during various routine, abnormal and emergency operations.

Technical Approach:

Portions of the work required to address this issue will have been accomplished by human factors solutions described elsewhere in this plan, i.e., the normal operations workload and communications required of personnel in bridge operations, cargo transfer, and port call operations. Extensions of the methodologies employed in these analyses will be used to address the broader issue of system information requirements during various modes of operation.

The initial work to accomplish for this task will be to develop enhanced analyses of the bridge, cargo transfer and port call workload and communication evaluations. The main product of these analyses will be task activity timelines for each person involved, and communication link tables. The present task involves extending these analyses to include the information requirements associated with the task activities and communications. The raw information concerning information flow and information type will be available on the basis of the Operational Sequence Diagrams (OSDs). However, the optimal distribution of information across personnel involved in a task will not be clear from the OSDs. To establish this information, it will be necessary to develop a Task/Personnel/Information Requirements (TPIR) form, and to obtain ratings of the frequency of use and criticality of various pieces of data for individual ship personnel to perform their jobs. For example, it may be desirable

but not critical for a lookout to know the exact compass heading of the ship; this information is necessary, however, for the watch officer to make navigation decisions or to communicate with other ships about intentions. Conversely, it is critical for both the helmsman and the watch officer to know the mode of operation of the autopilot. The purpose of the TPIR form is to formally document these requirements, based on a representative sample of shipboard personnel. The initial work should be based on the OSDs developed in the work described in solution numbers 7 - 9. Thus, the TPIR forms would be filled out for each of the scenarios evaluated in the workload analysis, for each task activity and communication link. This will cover bridge operations under routine and other conditions, as defined in that task, and cargo operations. Emergency conditions will need to be evaluated as a separate function, since communication links and task activities change dramatically from normal operations.

In order to expand the scope of this evaluation beyond bridge and cargo operations, a function analysis of other shipboard activities will need to be performed. This can be quickly done on the basis of previous function analyses (e.g., National Research Council, 1990). The analysis will delineate other important functions to assess from the standpoint of information requirements and distribution of information to ship personnel, e.g., engine operations, auxiliary equipment operations, administration, communications, and bunkering. While this list is not exhaustive, it illustrates a number functional areas that are served by one or more persons, that involve the transfer of information in multiple areas of the ship. Emergency functions that should be analyzed include firefighting, oil spill contingencies and abandon ship procedures. The specific list of functions to be evaluated should be determined on the basis of safety criticality, potential for error, complexity, and the potential influence of distributed information processing systems.

For each of the functional areas identified, a TPIR for should be developed. The forms will be somewhat different for each function, since the personnel involved will change. In most instances, there will be a few key personnel, and others are not involved at all. In emergency conditions, all personnel will be involved in some way, and the TPIR will closely resemble a station bill. As with the bridge and cargo functions discussed above, the TPIR will document the information requirements of individuals during the performance of their tasks which contribute to carrying out a particular function.

<u>Resources and Timetable for Accomplishment</u>:

1.0 staff years for 9 months; total = .75 staff years.

Products:

The results of this task will reflect the standard practices of multi-person functions, such as navigation, cargo operations, engine room procedures, etc., in terms of the specific information required to perform individual tasks, and the distribution of that information across personnel. These data will provide a valuable baseline for determining appropriate procedures for supporting shipboard functions with computer-based automation.

13. Evaluate User Interfaces of ARPA and ECDIS Type Displays with Respect to Existing UI Guidelines and Performance; Develop Design Criteria, Training Approaches and Performance Enhancement Aids

Description of the Problem:

Electronic aids to navigation have reached a level of sophistication that may challenge the knowledge of the average user. For example, certain ARPA technologies are able to plot up to 32 targets simultaneously; this is well beyond the human span of perception or memory, particularly in a dynamic situation involving moving traffic and other obstacles. Additionally, a variety of functions are provided, which mariners report using only a subset of, perhaps because of training limitations or lack of understanding. Similarly, ECDIS type displays offer the prospect of enhanced information manipulation by means of electronically representing paper charts, as well as eliminating manual track keeping and other repetitive functions. However, recent research (Aertz, 1991) has shown that there are costs in terms of navigational performance associated with making mental rotations of electronic map displays to correspond to the ship-centered reference. This indicates that there is potential to lose "situational awareness" during operations involving altered track types on electronic map displays. Further, research with software systems having nested functions (Shneiderman, 1987) indicates that there is potential to become "lost in the system." Because of the potential for enhancing navigation capability, it is important to more fully understand the implications of sophisticated electronic display systems from the human performance standpoint.

Technical Approach:

A multi-faceted approach will be used to evaluate the user interfaces of advanced navigation electronics. The approach will involve a combination of (1) evaluation of the user interface by human factors experts, (2) self-report of problems encountered in training and operation of navigation electronics, and (3) evaluation of user interaction protocols obtained in simulator settings. This combination of approaches will yield the richest findings in terms of potential design improvements.

Initially, a team of human factors specialists with expertise in user interface design and display will conduct an evaluation of selected ARPA and ECDIS technologies. The evaluation will be based on a number of existing user interface design guidelines, including those contained in ASTM F 1166, and others (e.g., Williges and Williges, 1984; Smith and Mosier, 1984; Schneiderman, 1987). These guidelines will be reviewed and condensed to a nominal checklist instrument, with items that will involve the experts verifying the existence of such features as HELP and BACKUP functions, orienting information to facilitate knowledge of location in a nested structure, and meaningfulness of graphically presented information.

To complement the human factors review of ARPA and ECDIS interfaces, a critical incident investigation of successes and problems with navigation electronics will be performed. Critical incidents refer to the circumstances surrounding particularly good or poor performance in a specific situation. For this work, it will be of interest to obtain descriptions from a number of experts who have had substantial experience with navigation displays, as well as persons who are just learning how to use them. These personnel can be accessed in a number of ways: through the Masters, Mates and Pilots unions, through local pilots associations, via merchant marine academies, and through training evaluations obtained by manufacturers.

A third approach to evaluating navigation electronics displays is to simulate particular navigation conditions, and to obtain performance and verbal protocols during simulated navigation. This can be accomplished in the Computer Aided Operations Research Facility (CAORF), or other simulator. The basic approach would be to vary the workload requirements of the primary navigation task, while also manipulating the complexity of the user interface (if possible) by requiring additional functions to be accessed, or less frequently used modes to be employed (such as collision avoidance alarms). Normative performance patterns will be compared with the actual behavior of mariners in the simulator, in terms of their reaction time, course deviations, communications decrements, and interactions with the equipment.

The information resulting from these three evaluation approaches will provide successively more refined data concerning the characteristics of navigation electronics user interfaces that either facilitate or inhibit successful task performance. At the surface level, the human factors expert evaluation will show where existing design standards and guidelines are not met. A somewhat more fine-grained level of information will be obtained by the self-report procedure. Here, mariners will discuss the types of errors (or performance successes) associated with various design features. Finally, the evaluation of performance under simulated navigation conditions will show where errors may be occurring that are probably self-correcting in most actual navigational situations. However, by showing where self-correcting errors occur, and their relationship to workload and equipment complexity, designers can begin to anticipate these potential flaws.

Resources and Timetable for Accomplishment:

1.25 staff years for 18 months; total = 1.875 staff years.

Products:

This task will result in three main products: (1) an expert evaluation of user interfaces from a static, non-operational standpoint; (2) a self-report compilation of how navigation electronics facilitates or yinhibits performance; and (3) behavioral and verbal protocols illustrating potentially dangerous situations related to user interface induced errors. The results will provide designers with a factual base from which to develop the next generation of navigation electronics displays.

14. Workload Analysis of Monitoring Task of VTS Operators

Description of the Problem:

The workload VTS operators experience monitoring ship traffic may affect performance either by reaching a level that exceeds their capacity, by dropping below a level that maintains their attention on the task, or by changing abruptly from low levels to high levels. Each of these instances has different consequences for performance and requires different human factors techniques to mitigate the effects on the performance of the operator. For example, monitoring as many as 20 targets simultaneously exceeds the operator's span of apprehension, leading the operator to shed tasks, ignoring some ships in order to direct more attention to critical ships. On the other hand, if an operator has very few ships to track, other tasks may distract the operator's attention. Finally, abrupt changes from low to high workload may lead to "cognitive tunnel vision" where the operator focuses on a single ship or task. With "cognitive tunnel vision" operators often fail to focus their attention on the most important aspect of the task, devoting attention to a ship many miles from shore as other ships go unobserved and pass dangerously close to each other. Examining the workload of VTS operators reveals whether operators suffer from overloading, underloading, or if the level of workload often shifts abruptly. This information will help identify techniques to mitigate these effects, such as training needs, memory aides, and display modification.

Technical Approach:

The principal objective of this technical approach consists of three components; each focused on the investigation of the workload of VTS operators as a means of increasing their effectiveness. The first component examines the feasibility of adapting workload measures to the VTS environment. The

second involves an assessment of the dynamics of the workload experienced by VTS operators. The third evaluates the possibility of mitigating the effects of workload through design changes, staffing modifications, or operator training.

<u>Phase 1</u>

In the first phase of this work, the numerous techniques available for workload measurement will be assessed for applicability to the VTS environment. Measurement of operator workload has had a long history in the aviation environment, and many of the measurement techniques applied to pilots may also apply to VTS operators. Many methods for estimating workload exist including the measurement of physiological changes, changes in operator performance, subjective ratings, calculated by estimating task demands, or by providing the operator with a secondary task and monitoring performance on the secondary task. Each of these general measurement techniques has its benefits and limitations, and the first step of the measurement process would be a selection of the appropriate technique based on particular limitations imposed by the VTS environment. The criteria for such a selection might include the sensitivity, diagnosticity, selectivity, obtrusiveness and bandwidth (Sheridan and Stassen, 1979). Sensitivity refers to the how well the measure reflects changes in the operators' level of workload, and diagnosticity refers to its ability to indicate the source of the change in workload. Selectivity, on the other hand, refers to the ability of the workload measure to reflect only changes in workload and not changes in such things as emotional states that are unrelated to mental workload. Especially critical to in the VTS environment are the characteristics of intrusiveness and bandwidth. Using workload measures on actual operators makes it imperative that it does not interfere with their normal duties, so it must not be intrusive. Bandwidth of the measure is also important because some workload measure would not reflect transient peaks in workload, while others would fail to reflect changes in workload that occur over hours instead of minutes.

In many instances, subjective ratings represent one of the most accurate and simple approaches to the measurement of mental workload (Moray, 1982). Therefore, either the Subjective Workload Assessment Technique (SWAT) or Task Load Index (TLX) might provide an accurate measure of workload associated with VTS monitoring. SWAT defines workload on three dimensions: time load, mental effort, or psychological stress. TLX, on the other hand, defines workload in terms of six dimensions: mental demands, physical demands, temporal demands, own performance, effort and frustration. With each of these scales operators rate their perceived workload on each of the dimensions. These scales have a long history, having been used to measure the workload of pilots for many years. Task-based estimates of workload, based on communication frequency and traffic density, might supplement subjective measures.

Evaluation of the techniques will be based on the criteria discussed above, and recommendations made regarding the most appropriate techniques to employ for VTS workload measurement. The recommendations will address any modifications that need to be made in order to adapt the selected techniques to the VTS environment. Additionally, Phase 1 will evaluate the potential workload measurement opportunities in terms of training simulators, operational work session recording via video or audio tape, and through observational means.

Phase 2

The second phase of this work will involve applying the recommended workload measures to the VTS operators. Using the data gathered by the various workload measures provides not only the overall level of workload of the VTS operators, but also a description of how workload varies during the shift. A characterization of the overall level of workload, as well as the dynamics of workload would lead to a better understanding of the demands placed on the operator and the possible errors induced by these demands. For example, long periods of low workload might lead to problems of vigilance (Mackworth, 1948), where the low level of activity might lead to operators overlooking ships or dangerous situations. Long periods of high workload, on the other hand, might lead to fatigue and a reduced ability to tract multiple targets. Rapid shifts in workload might have greater implications for performance than either consistently high levels of workload or consistently low levels of workload. Research has shown that people shift their strategies to adapt to the task demands (Raby and Wickens, 1990 and Rasmussen, 1986). Often these shifts are optimal, dropping less important tasks in favor of the more important; however other research has shown that people may not always be successful in reorganizing tasks to maximize performance (Segal and Wickens, 1990). Examining the ability of VTS operators to adapt to changes in workload will reveal how well operators reorganize their tasks when they encounter high workload. The workload measurements will be accomplished on the basis of the measures selected in Phase 1; depending on the nature of the measures, they will either be applied in vivo, or in a training simulation setting. Additionally, Phase 2 will investigate the potential of using video or audio tapes made during VTS operations as a source of behavioral and verbal protocol data, which have been shown to reflect workload variations. The precise design of the workload evaluation will depend on the measures selected, and the opportunities for measurement.

Phase 3

Overall, the characterization of VTS operator workload would provide a better description of the demands imposed on the VTS operator, in terms of the number of targets tracked, the communication requirements associated with those targets, data recording, and variation in workload throughout a work session. This description could then be used to generate a series of suggestions to enhance the performance of the VTS operator. For example, long periods of low workload punctuated by short

periods of high workload would might lead to specific design changes. Similarly, consistently high levels of workload might lead to other types of design changes. Examples of such design changes include hierarchical displays and decluttering functions. In addition to design changes, enhancing training would improve the ability of the operators to manage the specific workload situation they are likely to face. In addition to design and training modifications if the analysis reveals consistently high levels of workload this might suggest the need to increase VTS staffing.

<u>Resources and Timetable for Accomplishment</u>:

1.25 staff years for 12 months; total = 1.25 staff years.

<u>Products</u>:

The output of this task consists of three primary products; 1) specifications illustrating how to adapt workload measures for use in the VTS domain, 2) , a characterization of the dynamics of VTS operator workload that shows how the task demands associated with VTS monitoring might lead to certain kinds of errors, and 3) design and training recommendations that mitigate the effects of the workload of the VTS operators.

15. Develop Supplemental HF Information for Marine Safety Volume (MSM) on Casualty Investigation

Description of the Problem:

As many as 80% of marine casualties involve human factors root causes. However, the MSM volume on casualty investigation contains approximately one page of information on human factors. A Marine Investigation Module (MINMOD) has been developed that focuses on defining a human error taxonomy that will provide a more detailed level of information. However, such a taxonomy will be of little use unless there are complementary investigation tools to elicit information in a reliable, valid way. The MSM appears to focus primarily on administrative procedures, such as how to conduct a hearing and the form and contents of casualty reports. This volume needs to be supplemented with detailed descriptions of accident investigation techniques with a focus on eliciting human factors information.

Technical Approach:

Determine Types of Human Error Data Needed

The first task to be undertaken is a determination of what data need to be collected from casualty investigations in order to support CG casualty analyses of the human error component of accidents and incidents. This task will follow the typical top-down methodology used for the identification of measures of effectiveness/performance (MOES/MOPs; Erickson, 1986; Rau, 1974). Group interviews shall be held with members of those USCG headquarters divisions which require casualty data to support their analyses. The analyses currently being performed will be evaluated to ensure that they are consistent with the CG's underlying needs. Irrelevant analyses will be replaced by new analyses that are better focused on CG objectives. The desired level of data detail will be balanced with an eye to the feasibility of collecting specific types of data. The product of this task will be a set of well-defined MOEs/MOPs and a list of the casualty data needed to support them.

Changes to the HF taxonomy in the MIN Mod will be recommended in order to ensure that the proper data are being collected to support the MOEs/MOPs. If it appears that the current taxonomy does not cover the needed data well, it would be useful to consider alternatives. Other existing taxonomies used in accident databases could be reviewed and adapted for this purpose. Of particular relevance would be the ICAO Adrep listing which includes several human factors elements. Equally relevant would be the SHEL model developed by Edwards (1988) which explores human limitations, be they

physical, physiological, psychological, or psychosocial as well as other limiting factors such as the equipment and procedures used, the physical and organizational environment, and the interaction between each one of these components. It is important that this listing is not limited solely on human limitations but rather explores a wide range of factors which affect performance and could contribute to a marine casualty. Another source of relevant information would be the IMO guidelines on the role of the human elements in accident investigation.

Develop MSM Human Factors Information

Developing supplemental human factors information for the marine safety volume on casualty investigation requires more than just a set of separate tools. To elicit reliable and valid human factors information, the manual should provide investigators with tools that are part of a broader approach to accident investigation. Providing a theoretical framework to marine casualty investigation helps in understanding that the investigation of human factors is no different from any other investigations, that in fact, it is part of an investigation and that the tools it employs transfer easily to any other investigations. Human factors investigation goes beyond the search for "what" happened in an occurrence and aims at identifying information that will explain "why" it happened.

Such a broader approach should not only include a set of tools, such as guidelines, checklists and questionnaires, but should first provide investigators with a brief summary of a model of accident causation. Combining an approach to accident causation with a set of investigative tools not only allows investigators to have an overall understanding of the nature, role and impact of human factors information in marine casualties but also enables them to expand and adapt these tools to better suit the need of that particular investigation. Including a model of accident causation serves an important purpose by providing an integrating framework; however it should not be so extensive that investigators are lost in numerous theoretical concepts. Models and concepts presented should be brief, easily integrated with each other, and paralleled in the guidelines, checklists, and questionnaires.

Of relevance would be James Reason's approach to accident causation. His model has been adopted by the International Civil Aviation Organization as a valid approach to aircraft accidents/incidents investigation. ICAO has recently completed a digest on the investigation of human performance factors in which Reason's model is summarized and applied to an accident scenario. Similarly, it is our understanding that the International Maritime Organization (IMO) might also be considering adopting and promoting this same model to accident causation. Independently of the approach chosen, a model of accident causation should provide investigators with a description of: 1) the nature of accidents and incidents; 2) how they originate much beyond the actions of the people immediately involved; and 3) how other similar occurrences can be prevented.

The initial step to this project should be to contact other investigative agencies involved in marine and/or other transportation casualties. Amongst some of these investigative bodies are the National Transportation Safety Board, the Transportation Safety Board of Canada, or the Australian Bureau of Air Safety Investigation (BASI). Additional help and guidance should be available through other agencies such as the International Maritime Organization, the International Civil Aviation Organization, and other countries' equivalent to the Coast Guard. Most of these agencies have already in their possession various models, guidelines, checklists, or manuals of investigation. These documents should be reviewed and adapted to provide the Coast Guard with a more rational basis for determining the factors relevant to casualty investigation and better defining the scope covered by the each tool, be they guidelines, checklists, or questionnaires.

The next step will be to design a set of guidelines directed to help investigators in their approach to the gathering of human factors information. To better orient the investigators, guidelines should be divided according to the phase of the investigation, such as preparation prior to reaching the site, on site investigation, follow-up investigation upon return, and report writing. Guidelines should be broad enough to allow investigators freedom of actions within a particular phase, yet should be specific enough that crucial elements of an investigation be covered. When possible, guidelines should be linked briefly to the concepts and rationale presented in the theoretical framework. Towards the completion of this set of guidelines, interviews with experienced investigators in these agencies should be conducted in order to determine the validity and logic of these steps.

The final step in the development of supplemental human factors information for the Marine Safety Manual volume on casualty investigation is a questionnaire. This questionnaire should enable investigators to gather an extensive set of human factors information that they will compare against what is reported in the literature about the influence of these factors. This information provides the basis for an accurate analysis of their impact on the actual performance of the people involved in the occurrence, eventually establishing a link between these human factors and the causal factors. To contribute to the clarity of the document, the questionnaire's format should parallel the listing of human factors information and should contain questions that are sufficiently generic and broad to transfer to various cases and circumstances. To help formulate these questions, it could be useful to review interviews from actual investigation files. These questions should be formulated to extract the "why such an occurrence happened" rather than finding "what happened". For example, rather than asking if a mariner was fatigued during his watch, it would be better to find out when he went to sleep the night before, what work he performed over the previous watch, etc. Based on this detailed information, the investigator can draw tentative conclusions about the underlying causes of fatigue.

Finally, the purpose of these investigation tools is to provide investigators with the necessary information to facilitate the gathering and structuring of factual information and to preclude forgetting

important human performance information leading to a valid explanation of a causal factor. As a consequence, it is important to consult with experienced investigators in the field during this process, but more specifically when the checklist and questionnaires are being designed. These experts will provide a significant contribution in the listing of relevant human performance elements, the usability of such tools, and areas for which more information is needed.

Task Analysis of the Casualty Data Collection and Data Entry Process

Once the list of required casualty data has been defined, and the supporting tools are in place, it is necessary to determine whether all the needed data are routinely collected and entered via the current investigations process. It is important to understand what, if any, constraints are imposed upon the data collection and data entry processes, and how those constraints might affect the validity or completeness of the data. The data collection and entry process will be studied via a task analysis of casualty investigations and interviews with Investigative Officers. The task analysis and interviews will be used to identify the types of data which are not routinely collected (but needed to support HQ analyses), investigations, methodologies which might jeopardize the validity of the data and data entry problems which might inhibit the reliability or completeness of the data. A human factors review of the user interface for the MIN Mod shall be conducted. Recommendations shall be proposed for any additional investigations tool which might increase the validity of data or facilitate the collection of data which are not now routinely collected. Changes to the investigative and/or data entry procedures will be recommended, as well as any training required to support those procedures. After these changes have been implemented, the effectiveness will be evaluated through interviews with IOs and HQ analysts.

Resources and Timetable for Accomplishment:

1.25 staff years for 24 months; total = 2.5 staff years.

Products of the Task:

The primary product of this task will be a set of investigative tools that will be included in the Marine Safety Volume on casualty investigation. The purpose of this set of tools is to help investigators gather valid and accurate human factors information. It is essential that these tools be compatible with the actual Manual of Marine Safety and that they parallel and complement the proposed Marine Investigation Module (MIN Mod).

This set of tools will initially provide investigators with a short summary of a model of accident causation. A set of guidelines forms the second element of these investigative tools. These guidelines

should have for basis the model of accident causation presented initially and should offer investigators a step-by-step approach to any casualty investigation. The third component is a checklist or listing of human factors components or topics. This checklist or listing is an essential tool used by investigators to determine which elements are at play in a particular investigation. Finally, the addition of a questionnaire completes this set of investigative tools. The questionnaire should be designed to capture human factors information, especially during interviews.

16. Develop Human Factors Inspection Procedures and Criteria

Description of the Problem:

Aside from licensing, the inspection of vessels, offshore rigs, and shoreside facilities is the primary means the Coast Guard has for preventing marine casualties. The inspection process is used to determine whether vessels and facilities comply with regulations and guidelines to ensure the safety of our harbors and waterways. The inspection charter is being expanded to include human-related factors.

Human factors inspection criteria need to be developed, along with the appropriate tools, procedures, and training. The set of training, tools, procedures, and criteria developed must be usable not only by the Coast Guard, but also by third-party labs and shipping companies, who will become increasingly responsible for inspections over the next few years.

Technical Approach:

An understanding of current inspection procedures and the objectives for new human factors-related inspections will be provided through interviews with headquarters personnel and inspections officers and through observance of actual inspections of vessels, offshore rigs, and shoreside facilities. Since there are probably different sets of objectives and procedures for the inspection of vessels, offshore rigs, and shoreside facilities, they will be considered separately for the determination of human factors objectives, procedures and criteria. Moreover, if the types of inspections to be performed by shipping companies and third-party laboratories are to be different from those inspections performed by the Coast Guard, then separate sets of procedures and criteria must be developed for each type of inspector. A set of measures of effectiveness (MOEs) will be developed for human factors inspections of each type of facility and for each class of inspector (CG vs. shipping company vs. third-party). Inspection procedures and any necessary tools will be developed to allow the collection of the data which support the MOEs. Training materials will be developed for each class of inspector to ensure

that the objectives of the inspections are understood and that the procedures are carried out in an effective manner.

Resources and Timetable for Accomplishment:

1.25 staff years for 18 months; total = 1.875 staff years.

Products of the Task:

This task will produce inspections procedures for the human factors inspection of vessels, offshore rigs, and shoreside facilities. If needed, separate sets of MOEs, procedures, tools, and training materials will be produced for each class of inspector (CG, shipping company, and third-party lab) and for each facility type (vessel, offshore rig, and shoreside). These tools and procedures will ensure that each type of inspector is able to complete inspections to standards set by the USCG.

17. Conduct Organizational Analysis for Developing and Inspecting Emergency Pollution Response Capabilities

Description of the Problem:

The poor readiness of the Alyeska Company emergency pollution response capability has resulted in heightened awareness of the importance of developing and maintaining emergency response teams in both the public and private sector. In response to this heightened concern, a number of cooperatives have been developed in various areas of the country, as well as a national organization (the Marine Spill Response Corporation). Additionally, the Coast Guard is in the process of developing district-based response teams to supplement the capability of the geographically distributed National Strike Force. It is already apparent that there is some confusion among the existing organizations regarding jurisdictions, magnitude of spill to be responded to, and how to cooperate in the event of a major spill. Further, the Coast Guard currently has no well-developed criteria or procedures for determining the readiness level of the cooperatives, or job descriptions established for its internal teams. This situation can be clarified by establishing guidelines on a national level for the capabilities of an emergency spill response cooperative, and by defining procedures for levels of activation, given spills of various magnitude. The focus of this work is to develop a common definition of emergency pollution response that can be used to implement and inspect emergency response organizations.

Technical Approach:

Because the structure of an organization should flow from its expected functions, clear definitions of those functions are necessary to establish procedures for implementing and inspecting response organizations. The approach will begin by developing a conceptual model of the tasks necessary in an effective spill response. From this model and the prevailing regulations, the roles of cooperatives, Coast Guard teams, and other key actors can be discerned. The conceptual model will be developed through interviews and case history studies. Interviews would be conducted with response coordinators at previous oils spills, spill effects experts and cooperative operations managers. Case histories would involve structured reviews of documented histories of spills such as the Arco Anchorage in Port Angeles, WA, and the Exxon Valdez. The study team will be composed of personnel who have had experience in oil spill response, such as oceanographic engineers, and personnel with experience in emergency management.

Once the expected functions of the cooperatives and Coast Guard teams are established, analysis of performance requirements will support the development of performance and inspection criteria. The performance requirements will enable discernment of the equipment and supplies needed to support the organization's tasks and the training and command structure that its people need.

In determining the training and command structure of the cooperative or Coast Guard team, an analysis of decisions that the team and its individual members need to make will be performed. The availability of guidance from scientific teams or other sources will be considered in the analysis. These teams would include those concerned with damage assessment and effects, resource protection, and slick tracking.

Analysis of training requirements will also take into account any needs for specialized equipment training or operator certifications. Safety and hazardous waste handling training will be specified. Spill response is undergoing rapid evolution in its technology, and any assessment of training requirements will need to consider how to bring the personnel to the current state of the art. For example, in-situ burning and bioremediation are the subjects of current research and development efforts.

Frequently in spill response, a good organization can still be overwhelmed by the magnitude of the task before it. Through interviews and case history reviews, information will be gathered to determine realistic expectations of the performance of equipment and procedures under optimal and adverse conditions. This information will be used to establish criteria for judging the size and complexity of a spill to which an organization is capable of response.

An important aspect of a response organization's capability centers on timeliness. Information will be gathered to determine realistic expectations concerning how quickly an organization will be notified, what the time to deploy various elements would be, and the area over which such elements can be deployed. Although national level guidelines are sought, consideration will be given to how such guidelines may need modification in certain areas.

The readiness of an organization can be assessed with inspections of its equipment and records but, short of a real emergency, spill drills are the best way to assess readiness. Guidelines for both inspections and spill drills will be developed.

In spill drills, the capabilities to be evaluated include but are not limited to the following:

Notification procedures

- Can the organization be reached?

Mobilization profile

- How much of the response elements (i.e., both equipment and personnel) were deployed over what area in a given time?

Deployment control

- Were the appropriate response elements sent to the correct place?

Effectiveness

- Were the elements effective?
- If not, was there procedure to rapidly respond with alternatives?

Coordination

- Could the organization coordinate its people (e.g., did it know where they all were?)
- If in a lead role, could they coordinate the activities of others?
- If in a support role, could they discern the expected outcome sought and deliver such?

- How well do they get on with others?
- Where resource protection guidelines were given by resource agencies, were they communicated to the field and implemented correctly?

Safety

- How well was safety considered in the operational assignments?

A number of oil companies are already planning to hold annual spill drills with their response teams. The resource agencies are often included in these drills because of their role in identifying critical resources to be protected during the spill and spill response.

During inspections, the items to be examined include but are not limited to the following:

Verification of personnel status

Number of personnel in various job categories
Training records
Actual availability

Verification of equipment and supplies

Inventory
Readiness
Usability.

Inspections should not be substituted for drills if readiness is to be maintained over the long term.

Resources and Timetable for Accomplishment:

1.25 staff years for 12 months; total = 1.25 staff years.

Products:

The output of this task will be a prototype organizational model that can serve as the basis for establishing cooperation and decision making responsibility among the various regional cleanup resources. Additionally, guidelines will be developed for the composition and training of the cleanup team members, and for evaluating the capabilities of the team members and the overall readiness of response contractors.

18. Evaluation of Procedures for Shipboard Operations

Description of the Problem:

Procedures underlie the performance of most routine tasks in shipboard operations, as in other technical areas. They establish a sequence of operations to be followed for correct performance of some task or function. Most procedures are written and stored in close proximity to the area where the tasks will be performed. It has been found in the analysis of human error in the nuclear and aviation industries that failure to follow procedures is related to later accidents (e.g., Chernobyl and the Chicago DC-10 accidents). The National Transportation Safety Board report on the Exxon Valdez accident included numerous examples of failure to follow prescribed procedures. Work conducted on Human-Organization Error by University of California Berkeley (Bea & Moore, 1991) indicated that individual human error can often be linked to organizational problems. Analysis of procedural violations in the nuclear industry suggests that there are three principal reasons why procedures are not followed: (1) personnel think they know the procedure and do not need to make reference to it, (2) the procedure is unusable because of poor quality construction, and (3) personnel do not believe the procedure is applicable, or that certain steps are not applicable. There is little information available concerning the relative use of procedures in the maritime industries in terms of the content, frequency of use and quality of construction. In order to ensure better use of procedures for accomplishing various tasks, and to understand the best way to package these procedures (e.g., written versus computerized job aids), an evaluation of procedural use and utility in selected maritime operations should be conducted.

Technical Approach:

Since procedures will be used in a wide range of maritime activities, the first step in an evaluation will be to select several types of procedures that may be of greatest interest. The selection of procedures for evaluation should be based on criteria such as the complexity of task performance, the likelihood of error, and the frequency with which procedures are presently used. Another aspect of this evaluation should be an assessment of the level of awareness of and attitudes toward procedures by maritime personnel, e.g., standing orders for particular ships, company policies regarding operation etc. This initial phase of the work can be best accomplished by use of observational and interview techniques during ship and maintenance yard visits.

Based on the results of the first phase of work, selected procedures, such as maintenance operations (which will likely be procedure intensive) will be evaluated on the basis of guidelines established for procedures in other industries (e.g., Wieringa et al., in press). These guidelines include criteria such as the extent of forward reference usage (referring to more detailed explanations that have not yet appeared in the text), level of detail provided, and the application of graphics. The output of this evaluation would be a set of recommendations for enhancing the format or presentation media of written procedures.

A more complex issue related to procedures is that of the motivation to follow them. Since the Exxon Valdez accident was caused partially by the captain not following the standard operating procedure of being on the bridge, this issue is quite important. Studies in other industries have also found a disinclination to follow procedures (Barnes and Olson, in press). Thus, results from the initial interview data obtained in this task should be used to determine where further investigation may be fruitfully conducted. A straightforward prospect would be the analysis of marine casualty investigations to determine the extent to which personnel errors are related to failure to follow proper procedures. The reasons for these failures may illustrate ways in which the work setting or job could be restructured to increase the likelihood of procedural adherence.

An aspect of procedural adherence that will be difficult, but important to evaluate is the influence of organizational practices and policies on individual motivation. The approach that is most likely to yield valid data is either an anonymous survey, or a phone-in interview stimulated by a call for information to the maritime community. This latter type of approach is similar to the way in which a Marine Safety Reporting System (MSRS) was administered in the mid 1980s. This system suffered from a lack of reports, probably due to poor techniques for stimulating reporting. However, experience with similar systems in aviation (ASRS) has shown that specific calls for data can result in an extensive database of reports. The desirability of implementing such an approach will be evaluated with Coast Guard personnel, and if deemed feasible, such a survey will be undertaken.

<u>Resources and Timetable for Accomplishment</u>:

.75 staff years for 12 months; total = .75 staff years.

<u>Products</u>:

The evaluation of procedures will yield information concerning the extent to which written procedures for maritime jobs are properly designed and presented. Deficiencies that are discerned will result in recommendations for improvement; procedure guidelines from other industries may be adapted for incorporation into a NVIC. Interview and survey data will reflect the general attitude toward the

utility of written procedures, and provide an indication of broad areas warranting improvement. A survey/call-back study would provide useful detail on how work situations and organizational policies affect the motivation to follow procedures. These results could be used to recommend improvements in organizational communications.

19. Define Navigation Information Requirements for Mariners

Description of the Problem:

The Coast Guard designs its aids-to-navigation (ATON) system to ensure the safe and expeditious passage of vessels in U.S. waters. Many of the design principles governing the mix of aids, their placement in a waterway, and the selection of the hardware are driven by engineering considerations, often without regard to human performance and human-system interaction issues. This approach to aid system design sometimes yields systems that may be inadequate, causing mariners to spend excessive amounts of time acquiring the needed information, which interferes with navigating or driving their vessel. In addition, sometimes inconsistencies in the strategies used for marking waterways may contribute to navigation errors. The problem to be addressed is how one ensures that an ATON system is optimized for the human operator. The three major problem areas to be addressed are: (1) what should be the proper mix of aids-to-navigation, both now and as we head into the twenty-first century; (2) how can we improve the design of waterways with respect to the placement of aids; and (3) how can we increase the conspicuity of short-range aids? Each of these issues is further described below.

The ATON system has evolved over thousands of years, being updated each time a technological advance can be applied in the system. Differential GPS in concert with electronic charts have the potential to revolutionize navigation strategies, as it will provide accurate and reliable information about ownship position. The introduction of new technologies may require new approaches to aid system design and a change in the mix of ATONs. Reliance on short-range aids-to-navigation will likely decrease as electronic chart and GPS technologies become more affordable. The Coast Guard, in the interest of providing the best service to the user at the lowest cost must re-evaluate its system design and determine the appropriate mix of aids-to-navigation to meet its commitment to the public. This re-evaluation must be based on user requirements.

Good ATON system design maximizes the probability of safe passage. Until the late 1970's, the design of such systems was based on past practice, rules of thumb, and expert judgment. In 1978, the Coast Guard Office of Navigation began the development of an analytical tool to support the design and evaluation of aid systems. The effort began with an analysis of the support needed by the highest-

cost and highest-risk operations: the deep-draft vessel in restricted waterways. Over the next decade, performance data were collected on shiphandling simulators to represent the effects of channel configuration, vessel size and controllability characteristics, environmental forces, visibility and ambient light, and the density and placement of short-range aids. The results of these investigations were incorporated in a design manual for application to specific waterway problems. The last revision of the Waterway Design Manual (Smith, 1992) is presented being distributed. Given the present increasing use of electronic navigation systems, this type of systematic analysis should be available for electronic systems and should allow the examination of trade-offs among various types of systems. In addition, the needs of additional classes of users should be assessed.

Over the past eight years the Coast Guard R&D Center has conducted numerous studies to measure the effectiveness of visual signals. Studies have dealt with the detectability and recognizability of dayboard signals, the recognizability and detectability of Coast Guard lights, human perception and navigation performance of parallax range lights, the effects if buoy motion on detection and recognition, the effects of sequenced channel lighting on navigation performance, the effects signal size and intensity on conspicuity, the visual effectiveness of lasers as aids-to-navigation, to name a few. Even though great strides have been made, work needs to continue to order to improve conspicuity.

Technical Approach:

Mix of Aids-to-Navigation

In order to construct a useful aid mix for the future, it is necessary to understand how mariners use the aids available today. Task analyses will be performed of the navigation function on different vessel types, such as large ships, tugs, ferries, and recreational boats. Of particular interest will be what types of ATONs (buoys, racons, GPS, etc.) are understood and employed by the different types of users. The users will be interviewed as to their marine-related background, the types of navigation information they want or need, when the information is needed (e.g., at what distance from a hazard or channel boundary), their understanding of the information provided by different types of aids-to-navigation, and their reasons for using the aids they use.

An Aids Mix Working Group will then be formed, composed of personnel from the Office of Navigation and the R&DC Human Factors Group. This group will study the information gathered above and compare the needs of the users to the information available for present and potential aids. Alternative aids mixes will be considered. Simulator experiments will be designed and carried out to evaluate competing aids alternatives. Based on the results, the Working Group will recommend a new aids mix for the next century and provide a strategy for migrating from the present mix to the

proposed mix. The strategy should encompass any new regulations which would require certain equipment for different types of vessels for the sensing/reception of aids, training and information dissemination to make the public and commercial sectors aware of changes to the aids mix, and equipment and procedural changes required of the Coast Guard to establish and maintain the aids mix.

Waterway Design Process

Working with members of the Office of Navigation, the performance data needed for the design process will be planned. Much of the needed data should be available from simulator experiments done to evaluate the mix of aids needed for the various user groups. If necessary, additional simulator experiments will be done to provide missing data. These new findings will be incorporated into a new manual, or other analytic procedure, to allow more extensive design and evaluation of aids-to-navigation systems.

Conspicuity of Short-Range Aids

The recommended approach to designing conspicuous short-range aids is to use human performance data where they exist and to perform focused, small-scale experiments when the data do not exist. Basic visual performance data on detection thresholds, color discrimination, flash perception/discrimination, alignment sensitivity, etc., can be found in many human factors reference books. Often these existing data are sufficient to allow a designer to estimate the relative performance gains of a new device. When performance data do not exist, as in the case where the issue is the conspicuity of ATONs against "busy" harbor backgrounds, laboratory and field experiments must be conducted to evaluate the merits of one system over another. Human performance can be measured objectively and quantitatively if appropriate measures are chosen. For conspicuity of aids-to-navigation, an appropriate objective, quantitative measure is the time required to find a signal embedded in a background. Since more conspicuous signals will be found more quickly among background lights, experiments that measure the time to locate and identify different signals provide a method to compare conspicuity. The research effort to improve conspicuity should continue; the precise studies to be run will depend on the results of on-going efforts.

Resources and Timetable for Accomplishment:

TBD

Products of the Task:

This task will: (1) provide a recommendation for a new aids mix for the twenty-first century, as well as a strategy for migrating from the present mix to the proposed mix; (2) update the waterway design process to consider electronic navigation aids and additional user groups; and (3) improve the conspicuity of short-range aids.

20. Dissemination of Information to Mariners

Description of the Problem:

The Coast Guard disseminates information to mariners in several ways. For example, there are Navigation and Vessel Inspection Circulars, navigational charts in various periodicals, chart updates and navigation information broadcast over the radio. The Coast Guard does not know how mariners access and use the information. This task will evaluate the media used to disseminate information and recommend changes, if any, to make the information more easily available to the users.

Technical Approach:

Relevant members of the USCG headquarters staff will be interviewed to gain an understanding of the different types of information made available to the public, the media used to disseminate the information, and the types of vessels/operations most likely to need the data. One or more survey instruments will be developed and distributed to a variety of maritime users (e.g., fishing vessels, passenger vessels, shipping companies, shoreside and offshore facilities, pleasure craft owners, etc.). These surveys will collect information as to the availability, utility, and ease-of-use of USCG-disseminated information. Follow-up interviews will be held with selected respondents to get more details on problems and potential solutions. A report will summarize the findings and provide recommendations for changes in the way information is disseminated.

Resources and Timetable for Accomplishment:

1.0 staff years for 6 months; total = .5 staff years.

Products of the Task:

The products of this task will be a summary of how various types of CG-disseminated information to mariners is used and a set of recommendations for more effective dissemination/presentation of the information.

21. Develop Guidelines for Communication Between VTS and Vessels

Description of the Problem:

Communication between commercial vessels and the Vessel Traffic System is required by the Code of Federal Regulations (Part 33). Vessels are required to report 15 minutes prior to departure or arrival within a controlled area, and must monitor the appropriate communications channels. There is general agreement within both VTS and commercial vessel personnel that communications are not optimal; the issues involved include required response to VTS initiated communication during critical maneuvering, an apparent lack of responsiveness of ships to VTS communication, uncertainty on the part of the VTS as to which person member they are talking to, and VTS requesting information from ships (such as barometric pressure readings) that interfere with ongoing tasks. While these issues have been articulated, there is also general agreement that the system functions well. Thus, there appears to be a need for more structured communication protocols, i.e., general guidelines for who should contact VTS from the ship, the acknowledgements of communications, and the type and extent of information transfer.

Technical Approach:

Establishing communication guidelines should be a two-step process; the first step will be concerned with identifying the specific problem areas to be addressed, and the second with developing communication protocols or guidelines to mitigate the problems. The results will provide material with which VTS stations and shipping companies can train their workers for improved traffic-related communications.

In identifying the problems associated with current VTS - ship communications, a survey methodology employing a structured interview technique would be most appropriate. Since problems in communication will be best illustrated by examples, the interview should use the critical incident technique to obtain detailed descriptions of the events surrounding communications thought to be more and less useful. These descriptions should include the following aspects of communication: the initiator and respondent(s), the intent, prevailing conditions in terms of weather, traffic, time of day

and channel noise, and the specific contents of the communication. For each critical incident, the features that resulted in successful or unsuccessful communication should be identified.

The structured interview survey should be administered to VTS operators with varying levels of experience at stations throughout the United States. Geographic diversity in data collection is important because there may be special circumstances (such as icebergs) in particular locations that lead to increased communication requirements. Information should also be obtained from ship personnel routinely involved in VTS communications, including pilots, captains and mates who staff the bridge during transit in a VTS monitored area. Supplementary information to obtain includes data on company policies regarding radio communications, and any special bridge team organizations that have been developed to handle VTS communications.

Problems will be identified through content analysis of the interview data collected. Based on a preliminary review of the data, categories will be established for classification of individual responses. Clusters will be defined on the basis of multiple items occurring in the categories; statistical techniques can be used to predict a baseline rate, and clusters showing numbers of items above the baseline rate would be considered as candidates for the development of communication guidelines.

Since data have not been collected, it is not possible at this time to anticipate exactly what types of communication guidelines might be proposed. However, part of the work in developing solutions should involve an analysis of how communications take place in other types of traffic control centers, e.g., air traffic control and the developing centers for intelligent highway control (traffic management centers). In reviewing the procedures of these centers, particular attention will be devoted to the structure of communications, their content and frequency. Additionally, other VTS centers that have been set up by pilots associations (e.g., Long Beach) and in Canada should be evaluated.

<u>Resources and Timetable for Accomplishment</u>:

.75 staff years for 8 months; total = .5 staff years.

<u>Products of the Task</u>:

Two primary products will result from this task: (1) a statistically documented set of problems in VTS-shipboard communications in terms of frequency, required information, personnel and circumstances, and (2) a set of recommended procedures for normalizing communications so that a mutual understanding exists on either end of the communications channel. These recommendations will be influenced by an evaluation of traffic control communications in other transportation modes.

22. Organizational analysis of CG to support implementation of HF Plan

Description of the Problem:

The U.S. Coast Guard is organized along functional lines, such as Law Enforcement, Marine Safety and Engineering. Human factors issues tend to encompass the concerns of several functional organizations. For example, human factors concerns are evident in the design of aids to navigation, commercial ship electronics, and vessel traffic systems. It is unrealistic to expect that each functional office within the Coast Guard employ a trained human factors specialist to ensure that the human operator is considered in design and regulation. Further, because of the importance of setting internationally agreed upon standards, it is important that human factors safety issues be developed in conjunction with the efforts of the International Maritime Organization. While the Human Factors Coordinating Committee of the Marine Safety Office has been empaneled, there is no focal point for human factors implementation across the diverse Coast Guard offices (although the R&D Center is the focal point for human factors research). In order to determine the best organizational structure for human factors plan implementation, an organizational design study should be undertaken to define the mission, structure and location of a dedicated headquarters human factors function. Previous contract work (AIM, 1989) has suggested the need for such a function, but did not provide sufficient specification to actually establish the activity.

Technical Approach:

The basic approach to this task should be to identify the USCG HQ offices, divisions and branches that perform engineering, regulatory, inspection and investigation activities that have human factors components. In order to identify these offices, an initial list of candidate offices should be compiled; the purpose of this initial list is to exclude those offices that are obviously not concerned with issues related to human factors, such as the offices of civil rights and chief counsel. On the basis of the list of selected offices, a review of the missions and briefing books should be conducted to identify activities that involve human factors. The goal of this exercise is simply to define a set of offices that will be the basis for deeper analysis and to determine areas for survey and interview questions, as described below.

Since the objective of the work is to provide a framework for organizational implementation of human factors, it is important to gain an understanding of the details of each office, division or group in terms of its activities that involve decisions or processes affecting human performance, either in USCG applications (such as personnel selection), or in the commercial maritime industries. To achieve this

understanding, an organizational survey of the groups on the selected list, described above, will be conducted. The survey will be developed on the basis of the briefing book and mission statement review, and in conjunction with a group of subject matter experts (SMEs) knowledgeable about HQ operations. Items on the survey should focus on the types of systems developed or overseen, the areas of the maritime environment regulated, the mechanisms of operation (e.g., design committees, study groups, engineering teams), and the informational aspects of operation (e.g., internal white papers, NVICs, guidance documents, technical reports, engineering specifications, statements of work, etc.). The survey should also define the links between offices, divisions and branches.

The information gathered in the survey will facilitate an understanding of where in the organization opportunities exist to introduce human factors, and how it might be best implemented for individual offices, divisions or branches. The data will reflect three principal organizational elements that are crucial to introducing human factors: (1) the extent to which human operators are involved in the activities or systems overseen by the office, (2) the means by which the office accomplishes its work, and (3) the links to other parts of the organization that have some bearing on the principal activity of an office. The survey results will be analyzed in such a way as to create an organizational model that illustrates the critical organizational process and functions for human factors. This model should be validated by follow-up interviews with members of each office, division or branch that has significant human factors potential. The intent of the organizational model is to provide sufficient breadth of scope and detail to determine the best way to implement human factors on an organizational scale.

In addition to surveying HQ offices, divisions and branches, the district field offices should be evaluated to determine the areas where human factors are significantly involved. It is likely that individual districts will have various developmental initiatives, special casualty problems, or unique inspection concerns that have human factors implications. By identifying these areas, it will be possible to implement an HQ human factors function that better supports the field offices.

An activity that should parallel the USCG organizational analysis is a review of the structure and function of human factors program offices within other transportation modes, and government agencies. Two models would be particularly worthy of study: the Federal Aviation Administration (FAA) and the National Highway Traffic Safety Administration (NHTSA). The FAA established a high-level human factors function in 1989, and has successfully created a matrix structure that entails human factors input to all major R&D efforts, as well as coordinating (and conducting in-house) a detailed program of applied human factors research, based on a national strategic plan. NHTSA has two offices concerned with human factors, located in the Branches of Crash Avoidance Research, and Program Evaluation. Both of these branches have long and successful histories of major applied research and development efforts that have resulted in the implementation of equipment based on human factors improvements, such as high-mount center brake lights. A number of other

organizational models of human factors can be found within government and industry, such as the Office of Manpower Accession in the Department of Defense, and individual military service laboratories. Interviews with key personnel in these agencies should be conducted in order to determine the critical aspects of their successes and failures. Similarly, the human factors organizations of selected systems manufacturers should be evaluated to gain insight regarding how human factors is integrated into the design, development and evaluation process. Potential industrial candidates include the Boeing Commercial Airplane Group, Ford Motor Company, and the IBM corporation.

The AIM report (1989) recommended a human factors program office structure, directed by an LCDR, and possibly staffed by one or more civilians. However, this structure was suggested without consideration of the function and needs of its users. Such a program office has the potential to be influential, but must be properly structured, well-placed organizationally, appropriately connected to its constituents, and involved in ongoing HQ operations at an appropriate rate. The purpose of the organizational study is to provide the necessary information to facilitate the development, structuring, and introduction of such a program office, and to preclude the frequent fate of human factors functions, i.e., "rubber-stamp design reviewers" or worse. In organizations that have not properly implemented human factors within their ongoing activities, such offices are often viewed as obstacles. However, with appropriate organizational design, facilitated by organizational analysis, human factors can be implemented in such a way as to facilitate, rather than hinder the systems development and regulatory efforts of its constituents.

<u>Resources and Timetable for Accomplishment</u>:

.6 staff years for 12 months; total = .65 staff years.

<u>Products of the Task:</u>

The primary product of this task will be a set of recommendations on where and how to implement a human factors program office within USCG HQ. These recommendations will be based on the findings of an HQ and district organizational survey, and the resulting model illustrating the processes, systems and mechanisms used by offices, divisions and branches that could benefit from human factors support. Further, the "lessons learned" from other large government and industrial organizations in implementing human factors will provide a basis for understanding the practical aspects of implementation.

23. Determine Impact of Sea Tour Length and Watch-standing Assignments on Fatigue and Performance

Description of the Problem:

OPA '90 specifies work hour limitations for personnel aboard oil tankers to be no more than 15 hours per 24, or 36 per 72. These work hour limitations assume that fatigue is primarily a "phasic" effect, i.e., fatigue is a short-term phenomenon that will diminish with a brief but sufficient rest period. The rule also assumes that all personnel on board will experience identical amounts of fatigue. However, evidence is accumulating that long job durations lead to "burnout" and lack of attention to performance, despite having adequate rest during a particular circadian period. Additionally, some trade routes such as the Alaska oil routes, entail chronically foul weather, which results in extreme physical fatigue because of sleep loss and balance compensation. Little is known about what may constitute a sufficient period of recovery under these conditions. Finally, the work limitations currently imposed by OPA '90 assume that each position on board the ship results in similar fatigue levels and recovery period requirements. This assumption is very likely to be inaccurate, since there are a variety of different watch-standing requirements, some of which permit a full eight hours of sleep during the night, and others which do not.

Technical Approach:

The approach to the problem described above requires two distinct enquiries, one which examines the issue of chronic fatigue resulting from excessively long sea-tours, an another which evaluates the impact of job content and watch-standing requirements on acute fatigue. The results of both investigations will facilitate the development of better guidance for vacation policies and work scheduling/watch duty sharing during sea duty. Research conducted by the Transportation Systems Center (Pollard, 1990) elucidates some of the global variables associated with fatigue, but was not designed to evaluate the effects of watch-standing requirements or sea tour duration.

Chronic fatigue and length of sea-tour

The literature on fatigue and human performance deals primarily with the impact of acute fatigue, rather than the effects of long-term time on the job. To address the problem of the influence of length of sea-tour and optimal vacation period, it is necessary to gather information about the impact of fatigue build-up over time, the performance decrements induced by such fatigue, and the off-work time required in order for performance decrements to return to a baseline level. It is likely that some information of this type can be obtained through a structured review of existing fatigue studies, in

essence through a meta-analysis of previous work. It will also be necessary to collect field data in order to verify hypotheses suggested by generalization of acute fatigue studies.

The meta-analysis of acute fatigue studies will focus on assembling data from previously conducted work in which human performance has been measured in relation to length of time on task, or duration of a sleep deprivation period. Examples of sources of such information are Hockey (1983) and Colquhoun, et al., (1988). The analysis will focus on defining a range of fatigue induction periods and performance decrements. Specific analytic techniques will be determined on the basis of the amount of data available, and may include correlational, regression and analysis of variance methods. The objective of the meta-analysis is to provide a basis for predicting the impacts of length of time on task and duration of recovery periods on the development of performance decrements and rate of recovery.

Since a meta-analysis is based on data from a variety of different fatigue induction and performance tasks, few of which may involve maritime duties, it will be necessary to obtain data from mariners at different points in their sea-tours. Because there is likely to be a bias toward reporting greater levels of fatigue than actually exist, or to intentionally degrade performance, a longitudinal study is not recommended. Instead, an appropriate cross-sectional design should be developed, which will involve collecting data from different mariners at different points in their sea tours. These data should include both performance and subjective measures, and if possible, supervisory ratings by ship riders who are not informed of how long the persons being rated have been on duty. To the extent possible, data should be collected from personnel with identical job responsibilities and watch-standing requirements. The data collected in this task will permit a comparison of the subjective feelings of fatigue, task performance decrements, and observer-based ratings at different voyage phases. A complementary approach to such data would be to collect responses from personnel with varying tour lengths on instruments that can be used to assess their cognitive functioning, such as the Cognitive Failures Questionnaire. Another variable that is important in the analysis of long tour induced fatigue is the expectation of tour length at its onset. It has been reported that personnel may report for duty expecting a tour length of 60 days, but serve 80 days because of lack of relief personnel. This additional factor may influence both fatigue and stress level, and should be assessed in this work.

<u>Fatigue and watch-standing requirements</u>

Empirical research (Colquhoun, et al., 1988) has demonstrated significant differences in circadian rhythm structure between day workers and watch standers, and variations in ratings of sleep length and quality, both of which are related to time of sleep onset. This pattern of data, along with the periodic demands on all human resources imposed by port calls, suggests that some positions may suffer from chronic fatigue because of the sleep structure required by watch-standing requirements. Experiments

with "close" watch systems involving time compression within the 24 hour period of on-duty time suggest that sleep quality improves. A "close" watch system involves compression of all duty time into a 10 to 12 hour period.

The principal question to be addressed by this work is the extent to which the altered sleep structure imposed by the various watch-standing requirements, and the disruption of sleep structure by port operations, leads to fatigue. Previous work in this area has focused either on sleep duration and quality, or on fatigue, but not to how the two are related. Further, the impact of individual job/watch structures has been evaluated in only a few subjects for a limited time.

In order to address this question, it will be necessary to gather data from a range of watch-standing positions in both deck and engineering departments, and from day workers. The best approach would be to obtain data from the same positions (e.g., licensed mates, engineers, ABs, stewards) across a number of ships operating in identical or similar trade routes. Ideally, data could be obtained across ships of a single company, operating, for example, in the Alaska oil trade. A further variant of this design would be to collect data from multiple ships in two different types of trade, for example, the Alaska oil trade, and the Trans-Pacific cargo trade. This would allow a comparison of port-call requirements on fatigue.

The principal data to be obtained in this work are ratings of sleep length, onset time(s), quality, fatigue and nature of the days work, i.e., open sea or port call. Previous field research of this sort suggests that the initial step in successful data gathering is to get management and union agreement to participate in the study. Most mariners complain of fatigue, but many do not take the time to provide data; it is likely that with organizational support, there will be a better data return rate. The second important factor in obtaining sufficient volume of data is to streamline the process. In order to do this, the best approach would be to make the data collection forms a part of the everyday paperwork associated with watch-standing, e.g., a status report filled out at the end of the second watch period of the day, with a minimum number of rating items. It appears that one of the problems with prior research in this area is a data collection form that is too time consuming. The approach advocated in this plan is to sacrifice numbers of survey items for numbers of survey participants. Data would be analyzed with conventional statistical methods to determine the impact of watch structure on fatigue.

<u>Resources and Timetable for Accomplishment</u>:

1.25 staff years for 18 months; total = 1.875 staff years.

Products of Task:

The products of this task will be data sets that better define the nature of the fatigue problem in the merchant marine. These data sets will be presented in a technical report describing the impact of sea-time on fatigue level, and the influence of watch structure on fatigue. The two data sets will be complementary; the first task will define the long-term effects of fatigue on personnel over the course of a sea voyage; the second task will define how that acute (and presumably chronic) fatigue is manifest in personnel with different work schedules, and the influence of workload transitions on fatigue. The data will be used to develop recommendations regarding work schedule and vacation policies, and for suggesting alternate watchkeeping schedules, either through compressed watch times, or rotating across sea tours to ease the impacts of sleep times.

24. **Conduct study of how individual companies and personnel structures have responded to work hour rules of OPA '90 and desirability of extending such rules to the entire U.S. merchant fleet**

Description of the Problem:

Because fatigue was determined to be a major contributor to the Exxon Valdez accident, a regulatory solution was developed (OPA '90) restricting work hours for tanker personnel to no more than 15 per 24, or 36 per 72 hour period. The reasoning is that by limiting work hours, debilitating fatigue will not ensue, hence reducing the potential for human error and its consequences. The work rule of OPA '90 has resulted in various responses among the major oil shipping companies; one company appears to handle the work rule limitation by using a shoreside cargo mate (also subject to the rule) to assist in cargo operations. Other companies have added another licensed crew member, or request riding relief personnel based on predicted voyage profiles. Two years have passed since the enactment of this rule, and it would be desirable to conduct an assessment of its effectiveness in reducing fatigue. In particular, it would be useful to know if limiting the work hours has resulted in more sleep time and thus less fatigue, or if it simply results in less work time, without corresponding rest. The impending use of fitness-for-duty tests with ship personnel is related to this issue, since fatigue is a major factor in performance on such tests. Further, the applicability of more extensive shoreside support in tanker operations may be an alternative solution to work-hour limitations, if such limitations are found to be ineffective in reducing fatigue.

Technical Approach:

This task will require a multi-layered approach, involving organizational analysis, work structure evaluation, and interviews or questionnaires administered to individual mariners. The focus of the work will be on major oil shipping companies, including companies whose ships are operated by agents and staffed by union (Master, Mates and Pilots) members. This type of multi-level approach is necessary, since organizational policies are determined by regulation, which in turn affects how work structures are implemented, and the corresponding effects on the human resources in terms of fatigue.

The initial task will be to send a letter to the various oil shipping companies and maritime agents that handle US flagged tankers, describing the objectives of the work. Subsequent telephone contact with key personnel will be made, and the organizational analysis will consist of a delineation of the policies and procedures regarding the OPA '90 work rules, such as the discretion of individual ship captains for requesting cargo assistance on the shoreside, the manning policies used to stay within the work-hour limitations, and the procedures used to document work hours.

Contact with the companies will also be used to evaluate the specific work structures used on the tankers, within the context of existing regulations requiring three watch systems. There may be, for example, potential for ships with daywork engineering personnel to supplement their cargo operations, if those s are appropriately cross-qualified. The frequency and success of the various types of work structures (and the corresponding manning scales and technological systems) will be documented in this portion of the task.

Analysis of the effects of work hour limitations on individual s will be conducted by means of interviews and questionnaires administered to s across a range of ships types (e.g., steam plant, diesel plant) requiring the different work structures and manning scales described earlier in the task. The intent of this portion of the work is to characterize the qualitative and quantitative changes in work and rest activities that has resulted from OPA '90, and to determine the effects on fatigue. Thus, it will be necessary to obtain retrospective reports from personnel who are intensively involved in cargo operations, e.g., the chief mate, regarding how they performed their work in the pre-OPA '90 period, and currently. It will be important to interview all categories of personnel (perhaps with the exception of the steward's department), since OPA '90 work hour limitations are applicable to all human resource categories.

Resources and Timetable for Accomplishment:

1.0 staff years for 6 months; total = .5 staff years.

Products of the Task:

The results of this task will provide documentation regarding the relative effectiveness of the OPA '90 work hour limitations, in terms of the potential benefits provided by reduced work hours, such as less fatigue, and the potential costs, such as increased human resource requirements. Additionally, the work will permit an assessment of the relative effectiveness of limiting work hours in the context of a watch-standing system that is inherently disruptive of sleep patterns. The work will provide a basis for guidance concerning work structures and practices that can result in the best use of the non-work time made available by OPA '90.

APPENDIX D

Prioritization of the Projects in the Human Factors Plan

(added by the U. S. Coast Guard
Research and Development Center)

APPENDIX D
PRIORITIZATION OF THE PROJECTS IN THE HUMAN FACTORS PLAN

As a result of the issue identification and content analysis processes, twenty-four potential human factors projects (or solution approaches) were defined. The details of these projects are presented in Appendix C. The final step in our planning process was to prioritize these projects. This appendix describes the prioritization process and presents the results.

Prioritization Method

The first step was to analyze the twenty-four solution approaches in Appendix C and determine the end-products of each. An end-product was defined as any information, tool, or procedure resulting from a solution approach which could be immediately applied to Coast Guard activities. For example, the technical approach for the project, "Job/Task Analysis of Shipboard Activities" (p. C-1), would result in four different end-products: (1) a collection of shipboard job task analyses for different platforms, (2) an analysis of the skills needed to perform shipboard tasks, (3) an analysis of the training needed for these tasks compared with current training requirements, and (4) procedures for incorporating background checks into the licensing procedures. A total of 43 end-products were identified in the solution approaches. Because the Coast Guard might consider certain end-products to be more valuable than others, it was decided that each end-product should be prioritized, rather than just prioritizing the 24 solution approaches. The analysis also identified those end-products which were necessary precursors to other end-products. This was necessary to ensure that required, albeit "less popular", end-products were not inadvertantly left out of the final set of recommended projects.

The headquarters divisions represented on the Human Factors Coordinating Committee were asked to rate each of the 43 end-products. A rating sheet was employed which gave a one- or two-sentence description of each of the end-products (see Attachment 1 at the end of this Appendix for end-product descriptions). Each division was asked to determine whether the end-products were "applicable" to their activities (i.e., whether the end-product fell within the division's domain). If a given end-product did *not* fall under the division's purview, then they were to mark it "not applicable". If a given end-product *did* fall within their domain, the division was to rate its priority as follows. A "high priority" rating was given if the end-product was perceived to be critical to the division's activities (i.e., the content was valuable and the need was time-critical). A "medium priority" rating was given if the end-product was perceived to be important to division activities, but was not time-critical. A "low

priority" rating was given if the end-product was perceived to be useful to division activities. An end-product was rated "do not fund" if the division did not feel that such an end-product would be useful to them.

After the divisions had rated all 43 end-products, they were asked to rank the five most important "high priority" end-products. In addition, each division was asked to list any projects that were planned or in progress which were related to the end-products and which should be considered in determining the timing or scope of the proposed human factors solution strategies.

Compilation of the Data

Eleven completed rating sheets were returned. Seven were from G-M (MIM, MI/R, MMI, MPS, MTH, MVI, MVP); three were from G-N (NRN, NSR, NVT); one was from MARAD. A cursory analysis of the data showed that there was much disagreement between divisions as to the perceived value of some of the end-products. 25% of the end-products received *both* "high priority" *and* "do not fund" ratings. Some of these conflicts appeared to represent differing interests between the Office of Marine Safety, Security and Environmental Protection and the Office of Navigation Safety and Waterway Services. Since G-M and G-N have very different responsibilities, and since they have separate funding for R&D projects, it was decided to analyze their data separately. Because the data from MI/R and MARAD attempted to encompass all aspects of maritime safety, and thus did not fit strictly within the purview of either G-M or G-N, these data were dropped from the analysis.

The remaining data were compiled in the following manner. Each rating category was assigned points as shown:

Rating Category	Points
Not Applicable	0
High Priority	3
Medium Priority	2
Low Priority	1
Do Not Fund	-1

There were a few cases in which a division rated an end-product as in-between two categories (such as "medium-low"). In those instances, the score assigned was the average of the two categories (e.g., "medium-low" was assigned 1.5 points). For each office, a total score was calculated for each end-product by adding up the points assigned by each division within that office. Since six G-M divisions were

represented, the G-M scores could potentially range from -6 (if all divisions rated an end-product as "do not fund") to +18 (if all divisions rated an end-product as "high priority"). For G-M, the actual scores ranged from 0 to 10. Three divisions from G-N were represented, so their scores could potentially range from -3 to +9. The actual G-N scores ranged from -1 to +9.

The ratings given by the divisions are presented in Tables D.1 (G-M) and D.2 (G-N). The end-products are grouped according to the number of "high priority" and "do not fund" ratings they received. They were grouped this way to highlight the amount of inter-divisional agreement or disagreement on the relative value of the end-products. Within a group, the end-products are listed in descending order of total score. Besides the total score, the average score and average rank are shown. The average score was calculated by dividing the total score by the number of divisions which considered the end-product to be within their purview (i.e., the number of divisions who rated an end-product as either high, medium, low, or do not fund). The average score reflects the average priority rating assigned to a given end-product, while the total score tends to be more reflective of the number of divisions interested in a given end-product. The average rank shows the average of the ranks assigned to those end-products which one or more divisions considered to be among their top priorities. Although the divisions were asked to rank their top five high-priority items, a couple divisions ranked more than five end-products, which accounts for the larger average ranks shown.

Table D.1. HF Plan Priorities for G-M

END-PRODUCTS	RATINGS BY DIVISION						RATINGS BY TYPE					SCORES		
	MIM	MMI	MPS	MTH	MVI	MVP	n/a	High	Med	Low	Do Not Fund	Tot Scr	Avg Scr	Avg Rank
≥2 high, 0 DNF														
27. HF inspect procs	M	n	M	H	H	n	2	2	2	0	0	10	2.5	3
23. MINMOD HF tax	H	H	n	H	n	n	3	3	0	0	0	9	3	1.7
25. HF checklist for IOs	H	H	n	H	n	n	3	3	0	0	0	9	3	2
34. disregard for procs	n	L	n	H	H	M	2	2	1	1	0	9	2.3	5
33. construct of procs	n	n	n	H	H	H/M	3	2.5	0.5	0	0	8.5	2.8	3
26. cas data collection	H	H	n	M	n	n	3	2	1	0	0	8	2.7	2.5
29. train'g-HF inspect	n	n	M	H	H	n	3	2	1	0	0	8	2.7	7
6. simulators for CG	n	n	n	H	n	H	3	2	0	0	0	6	3	
1 high, ≥1 med, 0 DNF														
28. tools for HF inspect	M	n	M	M	H	n	2	1	3	0	0	9	2.3	
14. workld/link bridge	n	n	M	L	n	H	3	1	1	1	0	6	2	
15. workld/link port	n	n	M	L	n	H	3	1	1	1	0	6	2	
16. workld/link cargo	n	n	M	L	n	H	3	1	1	1	0	6	2	
19. distrib of ship info	n	n	M	H	n	L	3	1	1	1	0	6	2	
24. MSM chapter on HF	n	H	n	M	n	L	3	1	1	1	0	6	2	3
3. training needs* 1	n	n	n	n	H*	M	4	1	1	0	0	5	2.5	
8. time in grade & KSA	n	n	n	M	n	H	4	1	1	0	0	5	2.5	5
12. training reqts-auto	n	n	n	H	n	M	4	1	1	0	0	5	2.5	7
1 high, 0 med, 0-1 low, 0 DNF														
11. cog demand of auto	n	n	n	H	n	M/L	4	1	0.5	0.5	0	4.5	2.3	6
13. train'g course mods	n	n	n	H	n	M/L	4	1	0.5	0.5	0	4.5	2.3	8
7. licens'g & train'g* 1	n	n	n	n	H*	L	4	1	0	1	0	4	2	
41. fatigue and sea tour	n	L	n	n	n	H	4	1	0	1	0	4	2	
42. fatigue and watch	n	L	n	n	n	H	4	1	0	1	0	4	2	2
43. response to OPA'90	n	n	n	n	n	H	5	1	0	0	0	3	3	
1. shipboard JTA	n	n	n	n	n	H	5	1	0	0	0	3	3	1
2. shipboard skills	n	n	n	n	n	H	5	1	0	0	0	3	3	
9. shipboard man model	n	n	n	n	n	H	5	1	0	0	0	3	3	3
10. focused man models	n	n	n	n	n	H	5	1	0	0	0	3	3	4

(cont.)

(Table D.1. HF Plan Priorities for G-M, cont.)

END-PRODUCTS	RATINGS BY DIVISION						RATINGS BY TYPE					SCORES		
	MIM	MMI	MPS	MTH	MVI	MVP	n/a	High	Med	Low	Do Not Fund	Tot Scr	Avg Scr	Avg Rank
0 high, 0 DNF														
20. anal of auto equip	n	n	n	M	n	M	4	0	2	0	0	4	2	
37. W'way Design Man.	n	n	n	M	n	n	5	0	1	0	0	2	2	
38. info to mariners	n	n	M	n	n	n	5	0	1	0	0	2	2	
21. VTC tasks/workload	n	n	n	L	n	n	5	0	0	1	0	1	1	
22. VTC equip, jobs	n	n	n	L	n	n	5	0	0	1	0	1	1	
31. criteria-spill size	L	n	n	n	n	n	5	0	0	1	0	1	1	
32. criteria-spill resp	L	n	n	n	n	n	5	0	0	1	0	1	1	
1 DNF														
40. HF Program Office	n	D	H	M	M	L	1	1	2	1	1	7	1.4	1
_17. NVICs on HF_*2,3	n	L	n	H	H	D*	2	2	0	1	1	6	1.5	5
_18. guidelines-alarms_*3	n	L	n	M	H	D*	2	1	1	1	1	5	1.3	5
5. simulator in av/CG	n	n	n	L	n	D	4	1	0	0	1	2	1	
4. background checks*2	M	n	n	n	n	D*	4	0	1	0	1	1	0.5	
No Interest														
30. training-oil spill	n	n	n	n	n	n	6	0	0	0	0	0	0	
35. new aids mix	n	n	n	n	n	n	6	0	0	0	0	0	0	
36. conspicuity of SRA	n	n	n	n	n	n	6	0	0	0	0	0	0	
39. VTS-vessel comms	n	n	n	n	n	n	6	0	0	0	0	0	0	

End-products shown in *italics* had scores ≥4 or were ranked as a top priority.

Notes:
- *1 for uninspected and small vessels
- *2 not considered "Human Factors"
- *3 industry is responsible for good design, not USCG

Table D.2. HF Plan Priorities for G-N

END-PRODUCTS	RATINGS BY DIVISION			RATINGS BY TYPE					SCORES		
	N R N	N S R	N V T	n/a	**High**	Med	Low	**Do Not Fund**	Tot Scr	Avg Scr	Avg Rank
≥2 high, 0 DNF											
38. info to mariners	H	H	H	0	**3**	0	0	**0**	9	3	1.5
11. cog demands of auto	L	H	H	0	**2**	0	1	**0**	7	2.33	
12. training reqts-auto	L	H	H	0	**2**	0	1	**0**	7	2.33	3
13. train'g course mods	L	H	H	0	**2**	0	1	**0**	7	2.33	
20. anal of auto equip	L	H	H	0	**2**	0	1	**0**	7	2.33	4
21. VTC tasks/workload	L	H	H	0	**2**	0	1	**0**	7	2.33	1
22. VTC equip, jobs	L	H	H	0	**2**	0	1	**0**	7	2.33	2
35. new aids mix	H	H	L	0	**2**	0	1	**0**	7	2.33	1.5
1 high, ≥1 med/low, 0 DNF											
39. VTS-vessel comms	L	M	H	0	1	1	1	**0**	6	2	3
3. training needs	n	H	L	1	1	0	1	**0**	4	2	
6. simulators for CG	L	H	n	1	1	0	1	**0**	4	2	
14. workld/link bridge	L	H	n	1	1	0	1	**0**	4	2	
37. W'way Design Man.	n	L	H	1	1	0	1	**0**	4	2	
1 high, 0 med/low, 0 DNF											
1. shipboard JTA*1	n	H*	n	2	1	0	0	**0**	3	3	
*2. shipboard skills**1	n	H*	n	2	1	0	0	**0**	3	3	4
9. shipboard man model*1	n	H*	n	2	1	0	0	**0**	3	3	

(cont.)

(Table D.2. HF Plan Priorities for G-N, cont.)

END-PRODUCTS	RATINGS BY DIVISION			RATINGS BY TYPE					SCORES		
	NRN	NSR	NVT	n/a	High	Med	Low	Do Not Fund	Tot Scr	Avg Scr	Avg Rank
0 high, 0 DNF											
5. simulator in av/CG	L	M	n	1	0	1	1	0	3	1.5	
8. time in grade & KSAs	n	M	L	1	0	1	1	0	3	1.5	
17. NVICs on HF	n	M	L	1	0	1	1	0	3	1.5	
36. conspicuity of SRA	n	M	L	1	0	1	1	0	3	1.5	
10. focused man models*1	n	M*	n	2	0	1	0	0	2	2	
30. training-oil spill	n	M	n	2	0	1	0	0	2	2	
33. construct'n of procs	n	M	n	2	0	1	0	0	2	2	
18. guidelines-alarms	n	L	L	1	0	0	2	0	2	1	
40. HF Program Office	L	L	n	1	0	0	2	0	2	1	
42. fatigue and watch	n	L	L	1	0	0	2	0	2	1	
7. licensing & training	n	L	n	2	0	0	1	0	1	1	
15. workld/link port	n	L	n	2	0	0	1	0	1	1	
16. workld/link cargo	n	L	n	2	0	0	1	0	1	1	
25. HF checklist for IOs	n	L	n	2	0	0	1	0	1	1	
26. cas data collection	n	L	n	2	0	0	1	0	1	1	
27. HF inspect procs	n	L	n	2	0	0	1	0	1	1	
31. criteria-spill size	n	L	n	2	0	0	1	0	1	1	
32. criteria-spill resp	n	L	n	2	0	0	1	0	1	1	
41. fatigue and sea tour	n	L	n	2	0	0	1	0	1	1	
No Interest											
4. background checks*2	n	D*	n	2	0	0	0	1	-1	-1	
19. distrib of ship info*3	n	D*	n	2	0	0	0	1	-1	-1	
34. disregard for procs*4	n	D*	n	2	0	0	0	1	-1	-1	
23. MINMOD HF tax	n	n	n	3	0	0	0	0	0	0	
24. MSM chapter on HF	n	n	n	3	0	0	0	0	0	0	
28. tools for HF inspect	n	n	n	3	0	0	0	0	0	0	
29. train'g-HF inspect	n	n	n	3	0	0	0	0	0	0	
43. response to OPA '90	n	n	n	3	0	0	0	0	0	0	

End-products shown in *italics* had scores ≥4 or were ranked as a top priority.

Notes:

* 1 for USCG vessels

* 2 not needed for USCG personnel

* 3 USCG watch standards take care of this

* 4 G-K (Safety) responsible for USCG procedures

Results

Forty of the forty-three end-products were rated as "high priority" by at least one division. G-M showed "no interest" (total score ≤0) in only four of the 43 end-products, and G-N showed no interest in a (different) set of eight end-products. In order to focus on the end-products of greater interest to the two offices, the following selection criteria were used. An end-product was considered to be "of interest" to an office if: (1) it received a total score ≥4, or (2) it was ranked as a top priority item by at least one division*. The rationale behind these criteria was that an end-product should be considered of value to at least two divisions within the office (thus, a minimum total score of 4), or it should be among the top-ranked issues for a single division before it merits the expenditure of R&D funds. Using these criteria, there were 28 end-products of interest to G-M and 14 end-products of interest to G-N (*italicized* items in Tables D.1 and D.2).

Three additional end-products were added back onto the list because they were required precursors to the ones of interest. These were end-product numbers 1 (G-N), 2 (G-M), and 5 (G-M and G-N). The selected end-products were then cross-referenced with the solution approaches in Appendix C to determine which of the original 24 projects were of interest to the two offices. Nineteen of the solution approaches were of interest in their entirety, and parts of two more solution approaches were also of interest. The three projects that were *not* of significant interest were: equipment and information requirements for routine, abnormal, and emergency situations (project 12 in App. C), organizational analysis for developing and inspecting emergency pollution response capabilities (project 17), and a study of shipping company responses to the OPA '90 work hour rules (project 24). (The fact that certain projects were not selected does not necessarily indicate disinterest in those areas; it merely indicates that such projects were not considered to be critical for human factors research and development.)

The projects of interest to G-M and G-N are shown in Tables D.3 and D.4, respectively. Five projects were of interest to both G-M and G-N, and these are shown in Table D.5. The project numbers shown in the tables refer to the project (technical approach) numbers in Appendix C. The projects in the tables are listed in descending order of total score (combined total score for Table D.5; the score for a given project is the average of the scores for its end-products). The projects of interest to both offices

* These criteria are arbitrary. Stricter criteria could be chosen to further reduce the number of end-products of interest.

focused on the design of and training requirements for automation, the potential use of simulators for training and certification, and workload on the bridge.

In Tables D.3 and D.4, other relevant projects, either planned or in progress, are indicated (the project names are listed in Table D.6). This does *not* mean that these other projects will satisfy all the goals of the proposed human factors projects: in many cases they will not. These other projects are mentioned because their goals and results should be considered to prevent a duplication of efforts.

Table D.3. Human Factors Projects of Interest to G-M

Projects	Total Score	Rank	Work Planned?*
16. Human Factors Inspections Procedures	9	5	No
18. Evaluation of Ship Procedures	9	4	No
15. Marine Casualty Investigations	8	2.3	'93a
22. Human Factors Program Office	7	1	No
10. HF NVICs/Reference Material	6	5	No
7. Workload/Link Analysis of Bridge†	6		'93b
8. Workload/Link Analysis of Port Call	6		'94b
9. Workload/Link Analysis of Cargo Ops	6		'94b
2. Simulators for Training/Certification†	6		'93f, '94c
11. Guidelines for Alarm Displays	5	5	No
6. Eval of Training for Automation†	5	7.5	'94c
5. Cognitive Analysis of Automation†	4.5	6	'94d
3. KSAs to Link Time-in-Grade w/ Exper.	4.5	5	'93k?
1. Job/Task Analyses of Ships**	4	1	'93b, '93k
13. HF Evaluation of ARPAs, ECDIS, etc.†	4		No
23. Sea Tour Length, Watch, and Fatigue	4	2	'93d
4. Manning Models	3	3.5	'92j, '93b

Note: Projects include those with scores ≥4 oi those ranked as a top priority.
* Refers to projects listed in Table D.6.
† Project also of interest to G-N.
** Excluding background checks for licensing.

Table D.4. Human Factors Projects of Interest to G-N

Projects	Total Score	Rank	Work Planned?*
20. Dissemination of Info to Mariners	9	1.5	'92h
5. Cognitive Analysis of Automation†	7		'94d
6. Eval. of Training for Automation†	7	3	'94c
13. HF Eval of ARPA, ECDIS, etc.†	7	4	No
14. Workload of VTS Operators	7	1.5	'93e
21. VTS-Vessel Communications	6	3	No
19. Define Nav Info Reqts for Mariners**	5.5	1.5	'93g
7. Workload and Link Analyses of Bridge†	4		'93b
2. Simulators for Training/Certification†	4		'93f, '94c
1. Job Task Analyses for CG Vessels††	3.5	4	'92

Note: Projects include those with scores ≥4 or those ranked as a top priority.
* Refers to projects listed in Table D.6.
† Project also of interest to G-M.
** Excluding research in conspicuity.
†† Excluding background checks.

Table D.5. Projects of Interest to Both G-M and G-N

Projects	G-M Total	G-N Total	Comb. Total
6. Evaluation of Training for Automation	5	7	12
5. Cognitive Analysis of Automation	4.5	7	11.5
13. HF Analysis of ECDIS, ARPA, etc.	4	7	11
2. Simulators for Training/Certification	6	4	10
7. Workload/Link Analysis of Bridge	6	4	10

Note: Projects include those with scores ≥4 or those ranked as a top priority.

Table D.6. Work In Progress/Planned

	Project	Project Manager
a	Human Factors in Casualty Investigations	R&DC
b	Minimum Manning Standards	R&DC
c	Qualifications & Training for Automated Ships	R&DC
d	Human Resource Mgt for Commercial Vessels	R&DC
e	Human Factors Analysis and Engineering for VTS	R&DC
f	Simulators (literature review), NAS Marine Board	MS/MVP
g	Waterways Mgmt including ATON and Mariner Performance	NSR
h	Local Notice to Mariners Study	NSR
i	Training Analysis for new WLB	NSR
j	Manning Model - MARAD and Argent Marine	MARAD
k	Training for Tanker Officers	MS/MVP
l	VTS 2000 Requirements Analysis	NVT

Interrelationships Between Projects

The Coast Guard is launching a broad attack on human factors problems of concern to maritime safety. In order to plan this research effectively, it is necessary to understand how some of these projects interrelate. Figure D-1a shows about half of the projects described in Appendix C (the boxes drawn with dashed lines are those projects which were not of significant interest to G-M or G-N). All of the projects shown, with the exception of project 21, are independent of other projects in the Human Factors Plan. In other words, these projects have no prerequisite tasks which must be completed before the project can start. Therefore, in terms of project planning, these projects can be initiated at any time. The exception, project 21, Communications Guidelines for VTS and Vessels, requires that a task analysis of VTS stations (project 14) be performed first.

Figure D-1b shows the remaining eleven projects in the Human Factors Plan. As can be seen, these projects are highly interrelated. Most of them depend on information derived from Project 1, Shipboard Job/Task Analysis. Four of the projects require information from two or more other projects; the Manning Models projects benefits from the input from six other tasks. The interrelationships seen here put some constraints on the ordering of these projects. This is *not* to say, for example, that the Shipboard Job/Task Analysis must be done *in its entirety* before any other project can be initiated. Rather, only those parts of Project 1 which impact the desired project must be performed. For example, if one is interested in Project 7, Workload/Link Analysis of the Bridge, then only the bridge-related job/task data would be needed from Project 1. As another example, there are parts of Project 4 which can be performed with only a high-level breakdown of shipboard functions. Therefore, not only is a detailed job/task analysis *not* required, but none of the other five projects need be started in order to develop a generic work-hours manning model. The more focused manning models described in Project 4 are the ones which require input from other tasks (Projects 5, 7, 8, 9, and 23).

Figure D-1 can be used for planning purposes as a quick reference to determine potential interactions between projects. The precise nature of these interactions depends on what parts of a given project one desires to perform. Attachment 2 to this appendix breaks out the different parts of each project and indicates any antecedents (prerequisites) for each part.

Fig. D-1a. Interrelationships Between Projects in the Human Factors Plan

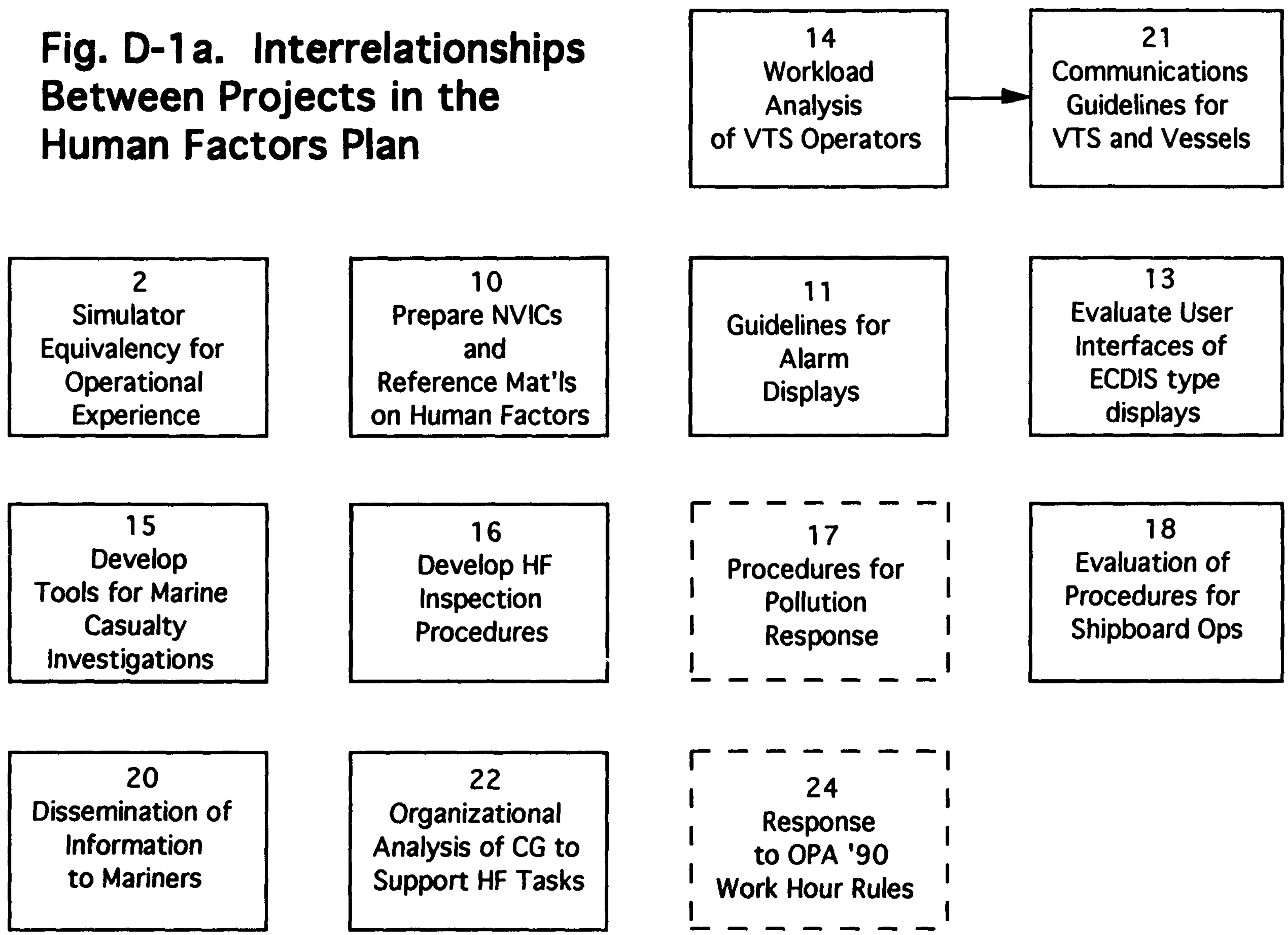
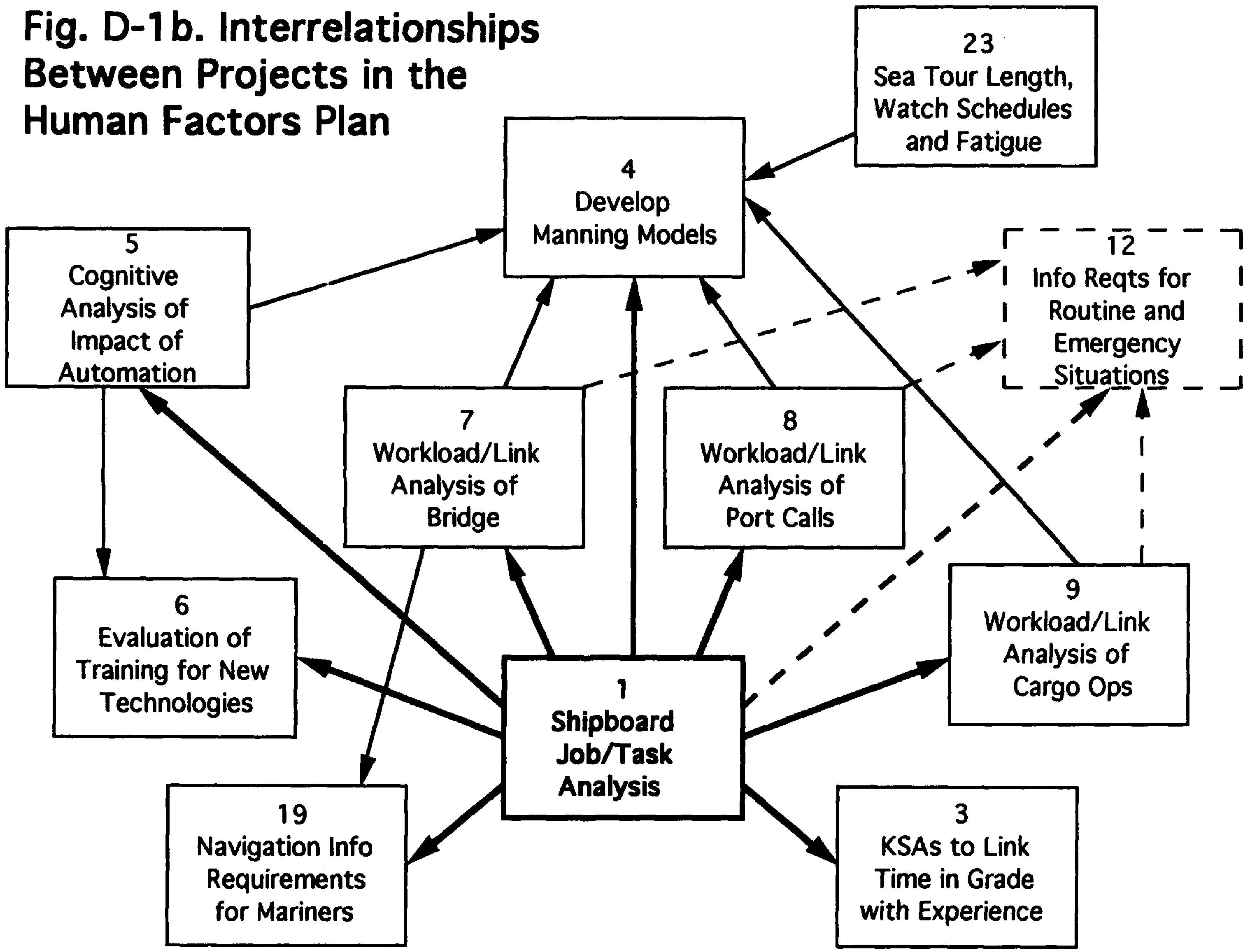


Fig. D-1b. Interrelationships Between Projects in the Human Factors Plan



Summary

Headquarters divisions in the Offices of G-M and G-N prioritized the proposed human factors research projects described in Appendix C of the Human Factors Plan. Of the twenty-four proposed projects, there was interest expressed for twenty-one of them. An analysis of the projects was performed to determine which projects (or parts of projects) depend upon input from other projects. It was found that there is a high degree of interrelation between about half of the projects in the Plan. The spreadsheet in Attachment 2 is provided to identify the specific tasks which are necessary precursors to a given project.

This appendix can be used to aid long-term planning of human factors projects for the Offices of G-M and G-N. It identifies those projects which are most valued by the various divisions within each office. It also identifies five projects which are of interest to *both* offices, indicating opportunities to conserve resources through jointly-sponsored research. Since the spreadsheet in Attachment 2 breaks out the various tasks for each project and their required precursors, it can be used to plan an orderly sequence of projects. In addition, the spreadsheet can be used to track the progress of these (and other, related) research efforts so that out-year projects can easily be planned to fill in any "gaps" no covered by earlier research.

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ATTACHMENT 1 TO APPENDIX D

List of End-Products from the Human Factors Plan

Below is the list of 43 end-products that were rated by the divisions in G-M and G-N. The end-products were identified via an analysis of the detailed technical approaches presented in Appendix C of this document.

MANNING, QUALIFICATIONS, AND LICENSING PROGRAM AREA

1. **shipboard JTA** - Job task analysis of shipboard tasks (descriptions of tasks performed by ship personnel). Range of platforms and operating conditions TBD.

2. **shipboard skills** - Analysis of the skills required to perform shipboard tasks.

3. **training needs** - Comparison of present training (offered through merchant marine academies and unions) and needed training for shipboard tasks.

4. **background checks** - Procedure for incorporating background checks (e.g., auto driving record, criminal record, etc.) into licensing procedure.

5. **simulators in aviation and USCG** - Comparison of use of/requirement for simulators by USCG and aviation. Simulator use in training and certification. Procedures used for approving simulators in aviation and USCG.

6. **simulators for USCG** - Recommendations for how USCG might incorporate simulators for training/certification. Recommend future work needed re: specific training objectives for simulators and procedures for use in proficiency checks/licensing.

7. **licensing and training** - Comparison of USCG licensing requirements with training required by shipping companies for specific positions on specific platforms.

8. **time in grade and KSAs** - Evaluation of the knowledge, skills, and abilities (KSAs) acquired by ship personnel. Determination of the degree to which time in grade equates to breadth of experience. Evaluation of utility of time in grade concept.

9. shipboard manning model - Development of shipboard manning model. Model will assist in determining numbers and types of personnel required for ship safety.

10. more focused manning model(s) - Development of more focused, more detailed model(s) of specific task/condition. Examples might include model for response to shipboard emergency, model of maintenance procedures, or impact of automation. In each case the numbers and types of personnel would be assessed.

AUTOMATION DESIGN APPROACHES PROGRAM AREA

11. cognitive demands of automation - Rough analysis of the cognitive demands and workload imposed on personnel for a given shipboard function (e.g., automation on bridge or in engine room), and how the degree of automation changes these demands. (Specific systems to study TBD.)

12. training reqts for automated systems - Assessment of skills needed to operate a given piece of automated equipment or perform a given automated function (specific equipment/function TBD).

13. training course modifications needed for automated systems - Comparison of current training courses with training required to operate a given piece of automated equipment or perform a given automated function. Recommendations for changes in training courses. (Specific equipment/functions TBD.)

14. workload data for bridge - Comprehensive data (task, information needs, and workload) on specific bridge operations (TBD). Detailed enough for designing/evaluating automated equipment. Valuable input to manning of specific bridge functions under different operating conditions.

15. workload data for port call - Comprehensive data (task, information needs, and workload) on port call operations (specific platforms TBD). Detailed enough for designing/evaluating automated equipment. Valuable input to manning of port call functions.

16. workload data for cargo transfer
- Comprehensive data (task, information needs, and workload) on cargo transfer operations (specific platforms and cargo TBD). Detailed enough for designing and

evaluating automated equipment. Valuable input to manning for cargo transfer functions.

17. **NVICs on HF** - Series of NVICs on topics such as ship design, the design of human-computer interfaces, equipment layouts, etc. NVICs will contain chapters on the human factors approaches to design and evaluation of equipment and structures, info on human capabilities, and detailed design guidelines.

18. **guidelines for alarms** - Guidelines for the design of effective, integrated alarm systems for shipboard applications.

19. **distribution of shipboard information** - Data requirements for different ship personnel under different operating conditions (e.g., cargo tank levels need to be displayed in the engine room to prevent overfills or pump burnouts). Specific functions and operating conditions TBD. Data detailed enough for use in equipment design.

20. **HF analysis of automated equipment** - Analysis of the strengths and weakness of ARPAs and ECDISs (or other automated equipment) from a human factors perspective. Recommendations for design changes to improve performance.

21. **VTC tasks and workload** - Data on VTC activities and VTS operator workload. Useful for evaluating staffing of VTC.

22. **VTC equipment and job design** - Recommendations on changes to VTS workstations and-or job design which would increase the effectiveness of VTS.

SAFETY PROCEDURES AND DATA PROGRAM AREA

23. **update MINMOD HF taxonomy** - HQ will re-evaluate its data analysis needs, and the HF taxonomy will be updated to meet those needs.

24. **MSM chapter on HF** - Write chapter for Marine Safety Manual on human factors aspects of casualty investigation, including the relationship of human factors to performance and casualties, and investigative procedures for determining human factors-related causes of accidents.

25. HF checklist for Investigative Officers (IOs) - Checklist or question-naire to assist IOs in collecting human factors data during a casualty investigation. It will be keyed to the MINMOD.

26. analysis of data collection and entry in casualty investigations - Analysis of problems in the collection and report of HF data. Recommendations for changes to tools or procedures used during casualty investigations (for HF data).

27. HF inspection procedures - Sets of procedures for the inspection of human factors-related elements for vessels, off-shore rigs, and shoreside facilities. Separate procedures will be developed for use by USCG, shipping companies, and third-party labs.

28. tools for HF inspections - Tools will be developed for use in the HF inspection of vessels, off-shore rigs, and shoreside facilities by USCG, shipping companies, and third-party labs.

29. training materials for HF inspections - Training materials will be developed for each type of facility (vessel, off-shore rig, shoreside facility) and for each type of inspector (USCG, shipping company, third-party lab).

30. training reqts for emergency pollution response - Analysis of the tasks required by USCG and other participants in oil spill response activities. Requirements for training and certification of participants, and requirements for specialized equipment.

31. criteria for judging complexity of spill response - Criteria for judging the size and complexity of a spill and for creating a realistic expectation of response by participants (performance and timeliness), given spill conditions.

32. criteria for evaluating spill response participants - Criteria for judging the performance of, and inspecting, participants. List of equipment and supplies required for task performance. Procedures for conducting an inspection of a given participant and for spill drills.

COMMUNICATIONS PROGRAM AREA

33. construction of procedures - Recommendations for improving the construction of procedures (format, detail, medium, etc.) in order to increase the likelihood that procedures will be understood and followed. (Specific procedures to analyze TBD. Examples might be maintenance procedures, or equipment operating procedures.)

34. disregard for procedures - Analysis of reasons why procedures (such as standard operating procedures or maintenance procedures) are disregarded, focusing on organizational factors. Recommendations for improving organizational communications regarding the following of procedures.

35. new aids mix - Analysis of needs and new technologies for aids to navigation. Recommendation for aids mix for the 21st century, and a migration strategy to deploy and support it.

36. conspicuity of short-range aids - Improved SRA design for better conspicuity.

37. expanded Waterway Design Manual - Addition of variables (e.g., multiple turns, variable currents, etc.) to the Waterway Design Manual and models.

38. dissemination of information to mariners - Analysis of strengths and weaknesses of current methods of information dissemination (e.g., chart updates, navigation information), and recommendations for improvements.

39. VTS-vessel communications protocol - Analysis of strengths and weaknesses of USCG VTS system communications protocols. Analysis of similar systems (air traffic, proposed intelligent highway system). Recommendations for changes to VTS-vessel comm protocol.

ORGANIZATIONAL PRACTICES PROGRAM AREA

40. HF Program Office at USCG HQ - Organizational analysis of USCG HQ offices and field offices with respect to human factors activities. Evaluation of similar HF programs in DOT and other government agencies. Recommendations on how to implement HF program office within USCG.

41. fatigue and sea tour length - Analysis of the impact of sea tour length on fatigue in merchant mariners. Recommendations on work and vacation schedules.

42. fatigue and watch-standing schedules - Analysis of the impact of watch schedules on fatigue in merchant mariners. Recommendations on watch schedules.

43. response to OPA '90 work hour rules - Data on the response of shipping companies and crews to the OPA '90 work hour rules. Data from crew members on changes in sleep/rest cycles and fatigue as a result of OPA '90. Evaluation of whether OPA '90 work hour rules are achieving desired results.

ATTACHMENT 2 TO APPENDIX D

Spreadsheet Analysis of Projects in the Human Factors Plan

The spreadsheet that follows can be used for detailed planning of human factors projects. The spreadsheet shows the project number and title (as given in Appendix C) and the tasks which must be performed within the project. Tasks were given hypenated numbers: the first number is the number of the project, and the second number is the task number (for example, 1-6 represents Project 1, Task 6, "perform more detailed JTAs..."). Project summary information is shown at the top of each sheet in **bold**. Task-specific information is provided below that.

The *Antecedents* column shows any antecedents (required precursors) to a given task (using the project-task numbering system explained above). Please note that antecedents from other projects refer back to the task product that is required; there are usually additional tasks in that project which need to be performed to provide that product. For example, task 3-2 (refine JTA info for platforms...) shows task 1-5 as an atecedent. Task 1-5 (perform JTAs) itself has antecedents (1-1, 1-3, and 1-4), all of which must be performed before starting task 3-2.

The *Task Products* column shows the results or output of each task. *Payoffs* are end-products of particular interest or use to the Coast Guard. Any other tasks which require the information or other product resulting from a given task are shown in the *Input To...* column. Finally, an estimate of the resources (in staff years) required to perform a project is given in the *Resource Estimate* column. These estimates come from Appendix C.

Project/Task Title	Antecedents	Task Products	Payoff	Input To...	Resource Estimate (staff yrs)
1. Job/Task Analysis of Shipboard Activities	**None (7, 8, and 9, if available)**	**JTAs for specific classes of position (e.g. deck officers), and specific classes of vessels**	**1. job task data 2. skills required to perform tasks 3. comparison of present trainin with needs 4. procedure for background dat checks in licensing**	**• manning model (Project 4) • training design of automated equipment • licensing**	**1.5 yr over 24 mo = 3.0 yrs**
1-1. obtain and review prior JTAs	None	historical JTAs		1-3, 1-5.	
1-2. review training school materials	None	current training practices		1-8, 6-2.	
1-3. define job classifications	1-1.	list of jobs to analyze		1-5, 1-6, 3-1.	
1-4. select or develop tools for JTA	None	JTA tools		1-5, 1-6, 7-2, 19-1.	
1-5. perform JTAs	1-1, 1-3, 1-4.	JTA data	1. shipboard job task data	1-6, 1-7, 1-8, 3-2, 3-3, 4-2, 5-1, 5-2, 6-1, 7-2, 8-1, 9-1, 12-3, 19-1.	
1-6. perform more detailed JTAs of human-machine and crew interactions for selected positions.	1-3, 1-4, 1-5.	more detailed JTA data for important tasks; more complete input for equipment design		1-7, 1-8, 4-2, 5-2, 12-3.	
1-7. assess skills required to perform JTA tasks.	1-5; 1-6 if available.		2. info on skills needed to perform tasks	3-3.	
1-8. compare JTA data with current training reqts	1-2, 1-5, 1-7; 1-6 if available.		3. comparison of present training with needs		

Project/Task Title	Antecedents	Task Products	Payoff	Input To...	Resource Estimate (staff yrs)
1-9. develop procedure for background checks of personnel	None.		4. procedure to incorporate background data in licensing decisions		

Project/Task Title	Antecedents	Task Products	Payoff	Input To...	Resource Estimate (staff yrs)
2. Establish Equivalencies for Simulator and Operational Experience for Different Ship Platforms			**1. Comparison of current USCG simulator approval procedures with those in aviation. 2. Recommendations for possible changes to CG procedures. 3. TBD, followup to recommendations.**	**• training, quals**	**.75 yr over 9 mo = .56 yr**
2-1. Review and evaluate USCG procedures for approving training courses and crediting simulator time for sea time.	none	Procedures for approving courses and trading off simulator for sea time. Identify weak links between sea time regulations and potential benefits from simulator training.		2-3.	
2-2. Review aviation procedures for crediting simulator time.	none	Aviation procedures for crediting simulator time.		2-3.	
2-3. Comparison between USCG and aviation procedures.	2-1, 2-2.		1. Comparison of current USCG simulator approval procedures with those in aviation. 2. Recommendations for possible changes to CG procedures, based on applicability of aviation procedures to marine environment.	2-4.	

Project/Task Title	Antecedents	Task Products	Payoff	Input To...	Resource Estimate (staff yrs)
2-4. TBD (based on results of 2-3) - possibly establish specific training objectives for simulator training course; improved procedures for proficiency checks.	2-3.		3. TBD		

Project/Task Title	Antecedents	Task Products	Payoff	Input To...	Resource Estimate (staff yrs)
3. Develop KSA Profiles to Link Time in Grade Licens Requirements with Type of Experience	**1-3, 1-5, 1-7.**		**1. Examples of training required by law vs. training required by shipping companies for specific platforms, etc.** **2. evaluation of value of time in grade requirements.**	**Training and licensing requirements.**	**1.0 yr over 12 mo = 1.0 yr**
3-1. Determine scope of effort (platforms, nationalities of interest), via review of casualty data and shipping company policies for mariner qualification.	1-3.	project scope		3-2.	
3-2. Refine JTA info for platforms or nationalities of interest.	3-1, 1-5.	More precise description of job functions based on specific platforms.		3-3, 3-4.	
3-3. Develop KSA transfer matrix.	1-5, 1-7, 3-2.		1. examples of training required by law vs. training required by shipping companies for specific platforms, etc.	3-4.	
3-4. Analyze degree to which time in grade equates to breadth of experience.	3-2, 3-3.		2. evaluation of value of time in grade requirements.		

Project/Task Title	Antecedents	Task Products	Payoff	Input To...	Resource Estimate (staff yrs)
4. Develop Tools to Assess Changes in Manning Structure on Ship Safety	**1, 5, 7, 8, 9, 23, as needed.**		**1. Shipboard model to assess training and staffing reqts. 2. More detailed models for specific activities (e.g., emergency response, maintenance, automation impact).**	**• Manning decisions. • Input to design of automated systems. • Procedures for maintenance, emergency response, etc.**	**TBD min. est: 0.75 yr over 21 mo = 1.3 yrs (4-1, 4-3 to 4-5)**
4-1. Develop detailed specifications for the model, including how it is to be used, the desired outputs, etc.	none.	Data, function, software, and hardware requirements for tool.		4-2, 4-3.	1.0 yr over 3 mo = 0.25 yr
4-2. Based on the data requirements, review JTAs, etc., and collect any needed data; develop any needed tools.	4-1; 1-5, 1-6, 5-4, 7-3, 7-4, 7-5, 8-4, 9-2, 9-3, 9-4, 23-1, 23-2, 23-3, 23-4, as needed.	Data collection tools and detailed data on aspects of task performance.		4-3, 4-4, 4-5, 4-6, 4-7.	
4-3. Create model, based on specs, and incorporate performance data.	4-1, 4-2.	Model, ready for validation.		4-4.	
4-4. Validate model (verify outputs, compare to known data, collect additional data as needed).	4-2, 4-3, plus actual data from applying 4-2 and 4-3.	Comparison of actual to predicted performance. Data can be used to fine-tune the model and-or data collection methods.		4-5.	0.7 yr over 12 mo = 0.7 yr (4-3, 4-4)

Project/Task Title	Antecedents	Task Products	Payoff	Input To...	Resource Estimate (staff yrs)
4-5. Perform sensitivity analyses to determine which activities affect ship safety (or other variable) the most. If desired, modify model to better reflect changes in these critical activities.	4-2, 4-4; additional data as needed.		1. Manning model which meets specifications.	4-6, 4-7.	0.7 y over 6 mo = .35 staff yr (4-5 and specs for 4-6)
4-6. If desired, develop one or more focused models (e.g., emergency response, maintenance, impact of automation). Repeat 4-1 to 4-5 as needed.	4-2, 4-5; additional data and specs as needed.		2. More focused manning models (e.g., emergency response, maintenance, impact of automation).	4-7. manning decisions; design of automated equipment; maintenance procedures.	1.0 yr over 9 mo = 0.75 yr (to develop 1 or 2 focused models; data collection not included)
4-7. As shipboard operations change (e.g., new automation, manning changes), collect data to compare to model predictions. Adjust model as needed.	4-2; 4-5 or 4-6; additional data as needed.	Updated model to reflect changes in shipboard operations.			

Project/Task Title	Antecedents	Task Products	Payoff	Input To...	Resource Estimate (staff yrs)
5. Cognitive Tradeoff Analysis of Automation Impact	**1-5 (and 1-6, if available).**		**1. description of the cognitive demands imposed on the crew for a given shipboard function, and how automation changes these demands.**	**• manning of automated systems • manning model (Project 4)**	**.6 yrs over 9 mo = .45 yrs (per automated system ?)**
5-1. Add cognitive requirements to shipboard function analyses.	1-5.	cognitive taxonomy		5-2.	
5-2. Determine relative levels of cognitive demand for shipboard functions and equipments of interest.	5-1, 1-5 (and 1-6 if available).	cognitive requirements of tasks		5-3, 5-4.	
5-3. Rate the relative importance of cognitive processes in automated and manual tasks; estimate workload.	5-2.	importance of cognitive tasks		5-4.	
5-4. Develop cognitive profiles of shipboard functions of interest.	5-2, 5-3.		1. description of the cognitive demands imposed on the crew for a given shipboard function, and how automation changes these demands.	4-2, 6-1.	

Project/Task Title	Antecedents	Task Products	Payoff	Input To...	Resource Estimate (staff yrs)
6. Evaluation of Training In Support of New Technologies	**1-2, 1-5, and simul-taneous with or after 5-4.**		**1. Identification of skills needed to operate given equipment. 2. recommendations for modifying current training programs to me skill reqts.**	**training requirements**	**.5 yr over 6 mo = .25 yr (per tech)**
6-1. Evaluate current or future training reqts for given or proposed equipment via JTAs and critical incident reports.	1-5 and simultaneous with or after 5-4.		1. identification of skills needed to operate given equipment.	6-2.	
6-2. Compare training needs with current training courses.	1-2, 6-1.		2. recommendations for modifying current training programs to meet skill requirements.		

Project/Task Title	Antecedents	Task Products	Payoff	Input To...	Resource Estimate (staff yrs)
7. Workload/Link Analysis of Bridge Operations	**1-5, if available**		**1. comprehensive data on bridge ops under various conditions - input to manning and quals.** **2. data on workload as function operating conditions - input to manning changes and design of automation.**	**• manning model (Project 4)** **• manning, quals** **• design of automation** **• basis for one-man bridge evaluation** **• guidance for bridge team structure**	**1.25 yrs over 12 mo = 1.25 yrs**
7-1. Identify scenarios which capture the set of different operating conditions.		set of scenarios for task analysis		7-2.	
7-2. Construct task analyses for bridge personnel under each scenario.	7-1; (and 1-4 and 1-5, if available).		1. comprehensive data on bridge operations under various conditions - input to manning/qualifications.	7-3, 7-4 12-1, 19-1.	
7-3. Construct timeline analysis.	7-2.	allows direct comparison of workload and activities under various conditions.		7-5; 4-2.	
7-4. Determine and rate communications links, both among crew and between ship and VTS/other ships.	7-2.	link analysis data		7-5; 4-2, 12-1.	
7-5. Determine workload levels for personnel under each condition.	7-3, 7-4.	Shows how workload fluctuates for given personnel under different operating conditions.	2. data on workload as function of operating conditions - input to manning changes and design of automation.	4-2.	

Project/Task Title	Antecedents	Task Products	Payoff	Input To...	Resource Estimate (staff yrs)
8. Workload/Link Analysis of Port Call Requirements	**1-4 and 1-5, if available**		**1. reveals how proposed automation or manning changes would affect port ops 2. provides guidance for design of automation**	**• manning, quals • manning model (Project 4) • design of automation**	**0.6 yrs over 6 mo. = .36 yrs**
8-1. Perform physical workload analysis	1-4 and 1-5, if available	manual activities for each crew member	1. can reveal how proposed automation or manning changes would affect aspects of port ops	8-2, 8-3, 8-4, 12-1.	
8-2. Perform cognitive workload analysis	8-1.	data needs, coordination, and timeline for port ops	2. provides guidance for design of automation	8-4, 12-1.	
8-3. Perform link analysis	8-1; simultaneously with or after 8-2.	communications, including type, urgency, timeline	2. provides guidance for design of automation	8-4, 12-1.	
8-4. Combine analyses	8-1, 8-2, 8-3.	timeline of workload for each crew member		4-2.	

Project/Task Title	Antecedents	Task Products	Payoff	Input To...	Resource Estimate (staff yrs)
9. Workload/Link Analysis of Cargo Transfer Operations	**1-4 and 1-5, if available**		**1. comprehensive data on cargo transfer ops for different types of cargo 2. workload of crew members for various types of cargo**	**• manning, quals • manning model (Project 4) • design of automation • guide team structure and job redesign**	**.75 yrs over 6 mo = .375 yrs**
9-1. Construct task lists for different types of cargo transfer	1-4 and 1-5, if available	list of tasks for each crew member		9-2.	
9-2. Construct timeline analysis	9-1.	timeline of cargo transfer ops		9-3, 9-4, 4-2, 12-1.	
9-3. Perform link analysis	9-2.	communications, including type, urgency, timeline		9-4, 4-2, 12-1.	
9-4. Determine workload levels for personnel under each condition.	9-2, 9-3.	shows workload reqts for different types of cargo	1. comprehensive data on cargo transfer ops for different types of cargo 2. workload of crew members for various types of cargo	4-2.	

Project/Task Title	Antecedents	Task Products	Payoff	Input To...	Resource Estimate (staff yrs)
10. Re-write NVIC 89-04	**none.**		**1. A series of NVICs and reference materials to aid in the human factors design and evaluation of human-computer interfaces, equipment layouts, ship layouts, etc.**	**• equipment design • ship design**	**1.25 yrs over 12 mo = 1.25 yrs**
10-1. Determine what types of guidelines need to be produced and outline the contents of each.	none.	detailed "table of contents" for each NVIC to be produced		10-2.	
10-2. Write NVICs	10-1.	NVICs will contain human factors approaches and tools for concept, design, and evaluation phases of equipment and ship design. NVICs will also provide information on human capabilities so that designers can understand the rationale for design guidelines.	1. A series of NVICs to aid in the human factors design and evaluation of human-computer interfaces, equipment layouts, ship layouts, etc.		

Project/Task Title	Antecedents	Task Products	Payoff	Input To...	Resource Estimate (staff yrs)
11. Adapt Existing Guidelines for Alarm Display to the Maritime Environmen	**none.**		**1. Guidlines for effective, integrated alarm systems for shipboard applications.**	**• design of shipboard alarm systems**	**.75 yrs over 6 mo = .375 yrs**
11-1. Evaluate and adapt existing framework for alarm function in nuclear power plants to the marine environment.	none.	alarm design approaches, which proved effective in other industries, and which appear applicable to marine industry.		11-2.	
11-2. Recommend specific alarm design guidelines for shipboard applications.	11-1.		1. Guidlines for effective, integrated alarm systems for shipboard applications.		

Project/Task Title	Antecedents	Task Products	Payoff	Input To...	Resource Estimate (staff yrs)
12. Define Equipment and System Information Requirements of Crew Members for Various Routine, Abnormal and Emergency Situations	**1-5, 7-2, 7-4, 8-1, 8-2, 8-3, 9-2, 9-3**		**1. data requirements for different personnel under different operating conditions for bridge, cargo, and port ops. 2. same for other functions and op conditions.**	**• design of ship systems (information distribution)**	**1.0 yrs over 9 mo = .75 yrs (bridge, cargo, & port ops only)**
12-1. Add data requirements to link analyses of bridge, cargo, and port ops.	7-2, 7-4, 8-1, 8-2, 8-3, 9-2, 9-3	Operational Sequence Diagrams (OSD) showing task timeline, infor-mation flow, and information type for bridge, cargo, and port ops.		12-2, 12-3.	
12-2. Develop Task-Personnel-Information Requirements (TPIR) form and rate frequency and criticality of information.	12-1.		1. data requirements for different personnel under different operating conditions for bridge, cargo, and port ops.	12-3.	
12-3. Expand scope to other ship functions or to abnormal or emergency conditions. Perform task and link analyses as needed.	12-1, 12-2, 1-5; 1-6, if available	Task and communications data for other functions and conditions.		12-4.	
12-4. Add data requirements to link analyses.	12-3.	OSDs for additional functions and operating conditions.		12-5.	
12-5. Develop TPIRs and rate frequency and criticality of information.	12-4.		2. data requirements for different personnel under different operating conditions and different functions.		

Project/Task Title	Antecedents	Task Products	Payoff	Input To...	Resource Estimate (staff yrs)
13. Evaluate User Interfaces of ARPA and ECDIS Type Displays; Develop Design Criteria, etc.	**none.**		**1. Analysis of pluses and minuses of current ARPAs and ECDISs.** **2. Recommend design changes to improve navigation performance.**		**1.25 yr over 18 mo = 1.875 yr**
13-1. Human Factors expert evaluation of interface design of selected ARPA and ECDIS instruments.	none.	Analysis of how well instruments adhere to human factors guidelines.	1. Analysis of pluses and minuses of current ARPAs and ECDISs.	13-2, 13-3, 13-4.	
13-2. Perform critical incident investigation of instruments.	13-1 (for knowledge of functionality).	Analysis of situations in which instruments performed well or poorly.	1. Analysis of pluses and minuses of current ARPAs and ECDISs.	13-4.	
13-3. Evaluate instruments via simulator experiments.	13-1 (for knowledge of functionality).	Effect of different interface designs on navigation performance under different operation conditions.	1. Analysis of pluses and minuses of current ARPAs and ECDISs.	13-4.	
13-4. Recommend design changes for ARPA and ECDIS.	13-1, 13-2, 13-3.		2. Recommend design changes to improve navigation performance.		

Project/Task Title	Antecedents	Task Products	Payoff	Input To...	Resource Estimate (staff yrs)
14. Workload Analysis of Monitoring Task of VTS Operators	**none.**		**1. Comprehensive data on VTS activities and workload. 2. Recommendations on changes to VTS equipment or job design which would increase the effectiveness of VTS operators.**	**• manning for VTS • VTS-vessel communications • design of VTS equipment**	**1.6 yr over 12 mo = 1.6 yr**
14-1. Select workload measures applicable to VTS environment	none (or simultaneously with 14-2).	identification of appropriate workload measures and an implementation plan		14-3.	
14-2. Task and link analyses of VTS operation	none.	data on job tasks performed by VTS operators and other VTS personnel.		14-3, 14-4, 21-1.	
14-3. Workload analysis of VTS operators	14-1, 14-2.	data on workload dynamics for VTS operators, and assessment of operators' ability to deal effectively with shifts in workload.	1. Comprehensive data on VTS activities and workload.	14-4, 21-1.	
14-4. Recommend changes to equipment or job design to increase effectiveness of VTS operators.	14-2, 14-3.		2. Recommendations on changes to VTS equipment or job design which would increase the effectiveness of VTS operators.		

Project/Task Title	Antecedents	Task Products	Payoff	Input To...	Resource Estimate (staff yrs)
15. Develop Supplemental HF Information for Marine Safety Volume on Casualty Investigation	**none.**		**1. Updated MINMOD HF taxonomy. 2. MSM chapter on theory and practice of HF data collection. 3. Tool to guide HF data collection during an investigation. 4. Recs for changes in tools/procs.**	**• casualty investigations • data analysis of causes of casualties • analysis of casualties to determine effects of new regulations**	**1.25 yr over 24 mo = 2.5 yr**
15-1. Determine types of human error data to be collected by MSIS.	none.	A set of well-defined MOEs required by the USCG and a list of casualty data needed to support them.		15-2.	
15-2. Change the HF taxonomy in the MINMOD to reflect data needed to support MOEs.	15-1.		1. Updated MINMOD HF taxonomy which meets data analysis needs to USCG.	15-6.	
15-3. Review and adapt models and documents used by other DOT agencies for accident investigation.	none.	A list of factors relevant to USCG accident investigations.		15-4.	
15-4. Design a set of guidelines on the gathering of human factors data.	15-3.		2. Guidelines (chapter in MSM) to increase comprehension of relationship of human factors to performance/casualties, and to aid IOs in collecting HF information relevant to a casualty investigation.	15-5, 15-6.	
15-5. Develop questionnaire which IOs can use to collect HF data during an investigation.	15-4.		3. Tool (checklist) to guide IOs in collecting HF info during an investigation.	15-6.	

Project/Task Title	Antecedents	Task Products	Payoff	Input To...	Resource Estimate (staff yrs)
15-6. Task analysis of the casualty data collection and data entry process	15-2, 15-4, 15-5.	Identify discrepancies between field implementation of HF investigations (methods used, data collected) and HQ's intentions for field implementation (required methods, data needed for analyses). Determine causes of discrepancies.	4. Analysis of problems in collection/report of HF data. Recommendations for changes to tools or procedures used during casualty investigations (for HF data).		

Project/Task Title	Antecedents	Task Products	Payoff	Input To...	Resource Estimate (staff yrs)
16. Develop Human Factors Inspection Procedures and Criteria	none.		**1. Procedures, 2. Tools, and 3. Training mat'ls for HF inspections of vessels, offshore rigs, and shoreside facilities performed by USCG, 3rd-party labs, and shipping companies.**	**• Inspection of vessels, off-shore rigs, and shoreside facilities**	**1.25 yr over 18 mo = 1.875 yr**
16-1. Determine objectives and MOEs for HF aspects of CG inspections.	none.	Understanding of current inspection procedures and objectives for HF aspects of inspections for vessels, offshore rigs, and shoreside facilities. MOEs for each type of inspection and inspector (CG, 3rd-party, shipping company).		16-2.	
16-2. Develop procedures for HF inspections of each facility type and for each inspector type.	16-1.		1. Procedures for HF inspections of vessels, offshore rigs, and shoreside facilities for use by CG, 3rd-party, and shipping companies.	16-3, 16-4.	
16-3. Produce tools to facilitate HF inspections of each facility type by each class of inspector.	16-2.		2. Tools to facilitate HF inspections.	16-4.	
16-4. Develop training materials for HF inspections of each facility type for each inspector type.	16-2, 16-3.		3. Training materials for HF inspections.		

Project/Task Title	Antecedents	Task Products	Payoff	Input To...	Resource Estimate (staff yrs)
17. Conduct Organizational Analysis for Developing and Inspecting Emergency Pollution Response Capabilities	**none. *Requires interdisciplinary team due to rapid advances in spill response technology.**		**1. Training reqts and specialized equipment needed for spill response. 2. Critleria for judging the size and complexity of a spill. 3. Criteria for evaluating participants.**	**• oil spill response planning and evaluation**	**1.25 yr over 12 mo = 1.25 yr**
17-1. Analyze past oil spills and interview response coordinators to determine the tasks for an effective spill response and the roles of CG, cooperatives, and others.	none.	Model of effective oil spill response, including task responsibilities of participants (USCG, cooperatives, and others).		17-2.	
17-2. Analyze performance reqts for spill response participants and develop performance and inspection criteria.	17-1.	Criteria for performance by, and inspection of, participants. List of equipment and supplies required to support each member's tasks.		17-3, 17-4, 17-5.	
17-3. Determine training and command structure for the participants.	17-2.	Effective command structure for participants. Training requirements.	1. Training reqts, certifications, and specialized equipment needed for spill response participants.		
17-4. Determine realistic performance expectations for participants, under optimal and adverse conditions.	17-2.		2. Criteria for judging the size and complexity of a spill and the expected response (performance and timeliness) from participants.	17-5.	

Project/Task Title	Antecedents	Task Products	Payoff	Input To...	Resource Estimate (staff yrs)
17-5. Develop guidelines for inspections of participants and for spill drills.	17-2, 17-4.		3. Criteria for evaluating participant's response, via inspections and spill drills.		

Project/Task Title	Antecedents	Task Products	Payoff	Input To...	Resource Estimate (staff yrs)
18. Evaluation of Procedures for Shipboard Operations	**none.**		**1. Recommendations for improving construction of procedures.** **2. Links between organizational factors and disregard for procedures; recommendations for improvement.**	**• a NVIC on procedure construction**	**.75 yr over 12 mo = .75 yr**
18-1. Select procedures for study based on complexity, likelihood of error, frequency of use, and personnel's attitudes towards use.	none.	set of procedures for study.		18-2.	
18-2. Evaluate selected procedures on their quality of construction (format, detail, etc.).	18-1.	pluses and minuses of construction of selected procedures	1. Recommendations for improving construction of procedures.	• a NVIC on procedure construction	
18-3. Determine when and why procedures are not followed by personnel.	18-1.	organizational and other factors which affect motivation to follow procedures.	2. Recommendations for improving organizational communications		

Project/Task Title	Antecedents	Task Products	Payoff	Input To...	Resource Estimate (staff yrs)
19. Define Navigation Information Requirements for Mariners	**none; 1-5 or 7-2, if available.**		**1. New aids mix and migration strategy to deploy and support it. 2. Better SRA design. 3. Expansion of the waterway design process.**	**• aids mix • design of short-range aids • waterway design**	**lots! (TBD)**
19-1. Perform task analyses of navigation on range of vessel types. Determine usage of aids-to-navigation (AtoNs).	none; 1-4 and1-5, or 7-2, if available.	Data on current vs. desired use of AtoNs by various types of vessels.		19-2, 19-4.	
19-2. Form Aids Mix Working Group; compare user needs to present and potential AtoNs; execute simulator experiments to evaluate competing aids mixes.	19-1.	Simulator data on pros and cons of various aids mixes.		19-3.	
19-3. Analyze regulatory, training, resource, and procedural consequences of competing aids mixes. Plan migration strategy to selected aid mix.	19-2.		1. New aids mix and migration strategy to deploy and support it.		
19-4. Continue work on conspicuity of short-range aids (SRAs).	none; 19-1, if available.	TBD (better SRA design)	2. TBD--better SRA design.		
19-5. Determine variables to be tested for expansion of waterway design process.	none.	Scope of task established.		19-6.	

Project/Task Title	Antecedents	Task Products	Payoff	Input To...	Resource Estimate (staff yrs)
19-6. Plan, execute, and analyze simulator experiments on selected variables.	19-5.	Effects of selected variables on navigation performance. Extension of existing waterway design models.	3. Addition of electronic aids and other classes of users to the waterway design process.		

Project/Task Title	Antecedents	Task Products	Payoff	Input To...	Resource Estimate (staff yrs)
20. Dissemination of Information to Mariners	**none.**		**1. Pros and cons of current info dissemination methods. 2. Recommendations to improve the system.**	**• Dissemination of NVICs, chart updates, nav info, etc.**	**1.0 yr over 6 mo = 0.5 yr**
20-1. Catalogue current methods used by the USCG to disseminate info to mariners.	none.	Data on current dissemination methods and to what types of mariners these are deemed relevant.		20-2.	
20-2. Develop, distribute, and analyze survey of information use by mariners.	20-1.	Data on perceived availability, ease-of-use, and utility of USCG info.	1. Pros and cons of current info dissemination methods. 2. Recommendations to improve the system.		

Project/Task Title	Antecedents	Task Products	Payoff	Input To...	Resource Estimate (staff yrs)
21. Develop Guidelines for Communication Between VTS and Vessels	**none; 14-2 and 14-3, if available.**		**1. Recommend changes to VTS communications protocols to mitigate problems.**	**• VTC operations • Regulation on VTS-vessel comms**	**.75 yr over 8 mo = 0.5 yr**
21-1. Identify problems associated with VTS-vessel communications via critical incident technique.	none; 14-2 and 14-3, if available.	Understanding of comm problems and types of comms felt to be valuable or not valuable by VTS and vessel operators.		21-2, 21-3.	
21-2. Evaluate other communications protocols (e.g., air traffic control).	21-1 (to understand relevance of other systems to VTS ops)	Analysis of similar systems and potential solutions that could be applied in marine environment.		21-3.	
21-3. Develop VTS comm protocols to mitigate the problems.	21-1, 21-2.		1. Recommend changes to VTS communications protocols to mitigate problems.		

Project/Task Title	Antecedents	Task Products	Payoff	Input To...	Resource Estimate (staff yrs)
22. Organizational Analysis of CG to Support Implementation of HF Tasks	**none.**		**1. Recommendations on how and where to implement a human factors program office within the USCG.**		**0.65 yr over 12 mo = 0.65 yr**
22-1. Identify USCG offices, divisions, branches, and field offices which perform activities which have HF components	none.	Define set of offices, etc., which could benefit from HF.		22-2.	
22-2. Perform organizational survey of selected offices, etc.	22-1.	Develop organizational model which depicts the critical organizational processes and functions for human factors.		22-4.	
22-3. Review structure and function of HF program offices within other DOT agencies and other government agencies.	none.	Analysis of critical aspects of successes and failures of HF program offices.		22-4.	
22-4. Evaluate survey data and program office review, and recommend USCG organization for HF.	22-2, 22-3.		1. Recommendations on how and where to implement a human factors program office within the USCG		

Project/Task Title	Antecedents	Task Products	Payoff	Input To...	Resource Estimate (staff yrs)
23. Determine Impact of Sea Tour Length and Watchstanding Assignments on Fatigue and Performance	**none.**		**1. data on the impact of sea tour length on chronic fatigue. 2. data on the impact of watch schedules on acute fatigue.**		**1.25 yr over 18 mo = 1.875 yr**
23-1. Analyze previous work on chronic fatigue related to length of sea tour	none.	model for predicting chronic fatique effects of length of duty and sleep deprivation.		23-2, 4-2.	
23-2. Collect chronic fatigue data from mariners	23-1.	objective and subjective indices of fatigue effects of sea tour length.		4-2.	
23-3. Analyze previous work on effect of watch-standing on acute fatigue	none.	model for predicting acute fatigue effects of watch schedule.		23-4, 4-2.	
23-4. Collect acute fatigue data from mariners on watch	23-3.	objective and subjective indices of fatigue effects of watch schedule.		4-2.	

Project/Task Title	Antecedents	Task Products	Payoff	Input To...	Resource Estimate (staff yrs)
24. Conduct Study of Company and Crew Structure Response to OPA '90 Work Hour Rules		**none.**	**1. data on qualitative and quantitative changes in sleep/rest and fatigue due to OPA '90**		**1.0 yr over 6 mo = 0.5 yr**
24-1. Conduct organizational analysis of shipping companies re: OPA '90 work hour rules	none.	company policies re: discretion of master for requesting assistance, manning, documentation of work hours, etc.		24-2, 24-3.	
24-2. Describe tanker work structure for each company	24-1.	implementation of three-watch system, cross-qualified crew members, etc.		24-3.	
24-3. Determine effects of work hour rules on individual crew members	24-1, 24-2.		1. data on qualitative and quantitative changes in sleep/rest and fatigue due to OPA '90		